# NEON

By

S. GOLD

# NEON

The Author has endeavoured to include the latest information and methods; and to visualise future developments in the use of Neon as an advertising illuminant.

As far as possible the use of technical phraseology has been avoided, but where a detailed description was found necessary, the Author was compelled to write in terms of anodes, cathodes, electrons and other equally elusive figures. He has however, prepared a Glossary of the various terms used, reference to which may be made from time to time so that the reader is cognisant of the general reading matter.—*From the Preface.*

To
Phyllis Adams

From
Hyde
Doman
1935

NEON

# NEON

*A Handbook*
*for Electrical Engineers*
*Neon Manufacturers, Sign Salesmen*
*and Advertisers*

BY

S. GOLD

*London*
CROSBY LOCKWOOD & SON LTD.
STATIONERS' HALL COURT, E.C.4
*1934*

FIRST PUBLISHED MCMXXXIV
BY CROSBY LOCKWOOD & SON LTD.
STATIONERS' HALL COURT
LONDON, E.C.4

## AGENTS

AUSTRALIA: *Robertson & Mullens Ltd.*
*107–113 Elizabeth Street, Melbourne.*

CHINA: *The Commercial Press Ltd.*
*211 Honan Road, Shanghai.*

INDIA: *Thacker, Spink & Company (1933) Ltd.*
*P.O. Box 54*
*3 Esplanade East, Calcutta.*

JAPAN: *Maruzen & Company Ltd.*
*6 Nihonbashi,*
*Tori-Nichome, Tokyo.*

NEW ZEALAND: *Whitcombe & Tombs Ltd.*
*Auckland, Christchurch, Dunedin, Wellington.*

SOUTH AFRICA: *Juta & Company Ltd.*
*P.O. Box 1010*
*43 Pritchard Street, Johannesburg.*

PRINTED IN GREAT BRITAIN BY
MORRISON AND GIBB LTD., LONDON AND EDINBURGH

# *PREFACE*

THE Author has endeavoured to include the latest information and methods ; and to visualise future developments in the use of Neon as an advertising illuminant.

As far as possible the use of technical phraseology has been avoided, but where a detailed description was found necessary, the Author was compelled to write in terms of anodes, cathodes, electrons and other equally elusive figures. He has, however, prepared a Glossary of the various terms used, reference to which may be made from time to time so that the reader is cognisant of the general reading matter.

Unfortunately, there is a dearth of technical information on Neon, and to supplement his own knowledge of the subject the Author has from time to time sought the advice of some of the best-known experts in their respective specialist lines. This help he fully appreciates, and in particular acknowledges the valuable assistance and collaboration of Mr. D. Hay Surgeoner, who has been largely responsible for the technical side of the work.

# *CONTENTS*


| SECTION | | PAGE |
|---|---|---|
| | Introduction | 1 |
| 1. | What Neon is | 5 |
| 2. | Tube Manufacture in Brief | 6 |
| 3. | Types of Neon Signs | 8 |
| 4. | Interchangeable Letters for Outside Signs | 14 |
| 5. | Double and Single Outline Letters | 14 |
| 6. | Colour and Diameter of Tubing for Outside Signs | 16 |
| 7. | Extent of Illumination from Neon | 20 |
| 8. | The Effect of Fog on Neon | 21 |
| 9. | The Use of Opal Tubing | 22 |
| 10. | Multi-Colour Tubes | 23 |
| 11. | Regulations regarding the fixing of Outside Neon Signs | 23 |
| 12. | What Type of Electric Supply is Necessary? | 27 |
| 13. | Current Consumption | 28 |
| 14. | Consumption of Neon compared with Bulb Signs | 30 |
| 15. | Backing Materials | 31 |
| 16. | Making and Installing a Neon Sign | 33 |
| 17. | Preparation of High Tension Cable Ends | 46 |
| 18. | "Earth Return" High Tension Wiring | 48 |
| 19. | Making and Erecting a Box Sign | 50 |
| 20. | Glass Panel Window Signs | 55 |
| 21. | Installing the Panel | 56 |
| 22. | Borders, Outline Tubes and their Fixing | 59 |
| 23. | Conversion of Trough-Letter Signs to Neon | 66 |
| 24. | Low Tension Wiring | 68 |
| 25. | Power Factor | 72 |
| 26. | Power Factor Correction | 76 |
| 27. | Control of Neon Signs by Time Switch | 79 |
| 28. | Flashers | 79 |
| 29. | Periodical Cleaning of the Tubes | 81 |

SECTION PAGE
30. Access for Maintenance . . . . . 83
31. Some Common Faults and their Location . 87
32. Elimination of Radio Interference . 90
33. Methods of Merchandising . . 92
34. On taking Particulars . . . 98
35. A Method of Calculating Tubing Footage . 100
36. Estimating the Job . . . . . 103
37. Manufacture of Neon Tubes . . . . 109
38. Conduction of Electricity through Gases . . 114
39. Striking Potentials . . . . . 121
40. Hysteresis . . . . . 122
41. The Complete Characteristic. Voltage-Current Relation . . . . . 123
42. Practical Applications of the Discharge Tube . 125
43. Positive Column Tubes . . . . . 127
44. The Hot Cathode Tube . . . . . 128
45. Manufacturing Sequence . . . . . 130
46. Preparation of Templates . . . 131
47. Washing the Glass . . . . . 132
48. Glass Bender's Equipment . . . . . 133
49. Glass Bending . . . . . 137
50. Pumps and Pumping . . . . . 141
51. Ageing of Tubes . . . . . 150
52. Transformers . . . . . 151
53. Condensers . . . . . 157
54. Electrodes . . . . . 158
55. Life of Tubes . . . . . 163
Glossary . . . . . 169
Index . . . . . 177

# *LIST OF ILLUSTRATIONS*


| | | PAGE |
|---|---|---|
| 1. | Box and Vee Signs | 10 |
| 2. | John Brown Sign | 35 |
| 3. | High Tension Wiring | 40 |
| 4. | Three Types of Insulating Glasses | 42 |
| 5. | Connection between Cable and Electrode | 43 |
| 6. | Simple Earth Return Wiring | 49 |
| 7. | Earth Return Wiring | 50 |
| 8. | Tube Supports | 51 |
| 9. | Parallel Type of Electrode | 64 |
| 10. | L.T. Wiring for D.C. | 70 |
| 11. | L.T. Wiring for A.C. | 71 |
| 12. | E.M.F. Curve for Simple Alternator | 73 |
| 13. | Lag of Current behind E.M.F. | 75 |
| 14. | Elimination of Radio Interference | 91 |
| 15 and 16. | Shell and Core Type Transformers | 154 |
| 17. | Life Test Tube | 164 |

# NEON

## *INTRODUCTION*

The Neon Sign, as we to-day know it, consists essentially of a glass tube bent to the form of either a letter or ornamental design, filled with a rare gas, and mounted to some form of background. Sealed into the ends of the tubes are two terminals or electrodes, and these electrodes are connected to an electricity source. On switching on this electricity, current is made to flow along the tube from one electrode to the other, and the passage of this current is responsible for the production of the glow inside the tube. Neon tubes do not have filaments. The conductor of the electric current is the rare gas with which the tube is filled, and whose nature decides the colour of the resultant glow.

Neon tubes cannot be operated directly from the usual 200/250 volts supply, as this voltage is not high enough to bring about the required discharge. To produce the requisite high voltage, a device known as a "transformer" is used. This consists of two coils of wire wound around an iron core, one coil being known as the "primary" and the other as the "secondary." The supply mains are connected to the two ends of the primary coil, and the electrodes of the tubing are connected to the two ends of the secondary coil. When the current is switched on, the flow of current in the primary coil causes a high voltage to be induced in the secondary coil and hence across the tube, and if the value of this voltage is sufficient, the tube will glow.

The name "Neon" tube is not strictly correct when applied to all forms of glowing tubes, but it has been used

to such an extent that it is now more or less generally accepted for universal application. The strictly correct name to apply to a gas-filled tube which glows when connected with a source of electricity is " luminous gas discharge tube." Neon tubes are those which are filled with the gas Neon, and which glow red when operating.

Luminous discharge tubes are not by any means a recent invention, and in fact are more of a natural scientific development than an invention. They date back to the early part of the nineteenth century, to the time when experiments in connection with vacuum pumps were being carried out.

Some of the earliest known discharge tubes were those made by a German, and named after him as " Geissler " tubes. These were made in the form of spirals, etc., or in some cases in the form of words, and were filled with the various gases which were then available, to produce different colours. These tubes were used largely in the laboratory for demonstration purposes, but we may consider them as being essentially similar to the modern " Neon " tube. Some Geissler tubes were used for display purposes in about the year 1887, but no information as to their success or reception by the public is available. At a later date, however, in about the year 1897, Geissler tubes were used successfully for a display commemorating the Diamond Jubilee of Queen Victoria, and this display was made possible by the discovery of two new gases by Lord Rayleigh and William Ramsay. To these two scientists we owe the subsequent discovery of the gas " Neon " and the development of what is now the " Neon Sign industry." It is interesting to note that the original discovery of Argon—which gas may be considered as primary to Neon—was made by the famous scientist Cavendish about one hundred and seventeen years previous to this time, although he was then not aware of the potentialities of his discovery.

The study of the properties of the atmosphere is one which requires great patience and greater skill, and after

the discovery of the two gases helium and argon in 1894 and 1895 respectively by Lord Rayleigh and William Ramsay, the latter, together with a Dr. Travers, set to work to isolate the whole of the gases which constitute what we know as "air." After three years' work they found in 1897 that in addition to helium and argon there were three other gases, these being mixed with argon and capable of separation from that gas only by the process of liquifying the argon. This process is known as the fractional distillation of liquid air, and it was only when the products of this process were being tested in a Geissler tube that the bright red glow now associated with neon was first observed.

The method of preparing the gas was at this time only in the laboratory stage, and could not be commercially applied with any degree of success. Subsequent development of the distillation process, however, led to greater supplies of neon becoming available, and when the use of argon for gas-filled electric lamps became general, large quantities of neon were produced more or less automatically, and this gas when purified became useful for the filling of neon signs. This occurred in about 1910, and between this time and 1920—the war period intervening—very little was done with neon signs. After the war, when bulb signs had almost reached their peak, the need for a supplementary illuminant was felt and neon was gradually adopted. The rate at which this adoption has increased may be judged from the fact that at the moment bulb signs are almost extinct except as supplementary to neon. This has been a perfectly logical development, as the sign-man can do as much or more with neon than he could do with bulbs, and at the same time produce a more effective display and a cheaper one.

The variety of colours available with neon is one of the factors largely responsible for the great popularity of this form of lighting. Pure Neon gives a bright orange-red glow which can be seen through fog and rain, whilst

Argon mixed with other gases and elements gives blue and green. Helium gives a pinkish white, whilst two other gases which are not used to any great extent are Krypton which gives a lilac, and Xenon which gives a bright blue. These latter two gases are very expensive to produce, and are not used except in very rare cases unless they are mixed with other gases. The mixing of gases plays an important part in the manufacture of neon signs, for it is by the use of mixtures with or without the addition of mercury, that the great variety of colours is made available, whilst the various shades are produced by using coloured glass. It has been definitely proved that no more new gases can be found for the simple reason that none exist, but there is still some field for exploration in the mixing of the gases which we can now obtain.

It is impossible to predict the possible future development of neon. Certain it is that there will be developments outside the field of signs and advertising, but how far these will occur need not concern us here. At the moment we are on the fringe or almost just within the edge of the range of application of the discharge tube, but this book is connected primarily with the particular application of neon to the sign industry.

The question of sign design is largely dependent upon contemporary thought, whilst construction depends upon the purpose of the sign and the architectural considerations.

Cost of operation is closely linked with developments in electric power transmission, whilst upkeep and maintenance costs are dependent upon the original layout.

The use of neon for aircraft signals is increasing, as also is its use for aerodrome lighting.

The application of neon as a secondary interior lighting medium is receiving attention, and for scientific work, neon is being increasingly employed.

At the present time neon is essentially an advertising medium, and as such must of necessity occupy a very

important place in our commercial life. Whether this importance increases or decreases in the future we cannot foretell, but we are confident that, for a considerable period at least, neon will find ever-increasing application.

## § 1. *WHAT NEON IS*

Neon is the name given to that class of illuminated sign which uses gas-filled glass tubes of small diameter as the illuminant. The tubes may be obtained in straight lengths of anything up to 12 feet, and also they may be bent to form any desired shape. The glass tubing is bent under the influence of heat, and this makes possible the production of the most intricate shapes and letters, etc. The tubing is fixed to a background of brick, wood, metal, or glass, and when a charge of electricity is applied at the electrodes of the tubing, these electrodes being fitted in the factory to the ends of the tubes, a bright glow results. The colour of this glow is decided by the nature of the gas inside the tube, together with the colour of the glass itself, the most commonly used colours being red, blue and green.

" Neon " means " the new one," and the gas we know by this name was so christened by William Ramsay and Dr. Morris Travers, its discoverers.

Neon is a rare gas extracted from the atmosphere by a process of fractional distillation, and when a current is passed through a tube filled with this gas at a low pressure, light is radiated and the tube " glows " with an intense flame colour. The heat generated during this radiation is very slight—most of the electrical energy being dissipated in the form of light—so that the tube runs practically cold even when it be left in circuit for twenty-four hours.

Argon, meaning " the lazy one," is another gas also extracted from the atmosphere, and under the action of an electrical current, glows with a violet-blue light. Argon is rarely used alone, however, as the colour is not sufficiently

intense, but when a trace of mercury is put into the tube the combined effect of this and the argon is to produce a pure cornflower-blue. Green is obtained by filling a yellow tube with argon and mercury.

For the production of a yellow or gold tube, helium gas is used and filled into a yellow or amber tube. Helium in a clear glass tube produces a pinkish-white glow, and for a clear white tube, helium should be filled into an opal glass tube.

Intermediate colours such as heliotrope, mauve, pale green and other shades, are obtained by using different colours of glass tubing filled with various gases and mixtures of gases.

## § 2. *TUBE MANUFACTURE IN BRIEF*

The manufacture of neon tubes is a very interesting process, and a verbal tour around a typical works will prove instructive.

The tube starts life in the form of a layout or drawing of the completed job. This drawing is made full size, and is executed in the reverse on a sheet of stiff brown or other paper. A substantial paper is necessary, as the glass bender works to this and often lays his glass on the paper to see that he is bending it correctly. If a thin paper were used, the heat from the glass would probably burn it and certainly scorch it. The reason for making the layouts in the reverse is that the tubes are bent so that their faces are flat, all the returns being kept at the back, and the bender therefore has to lay his tubing face downwards on the layout. The full-size layout is pinned to a large lay-out table covered with sheet asbestos to prevent burning.

The glass arrives in the form of " canes," each about 5 feet in length, and after being bent to the required shape, the tubes are passed into the washing department. The bending is carried out with the aid of bench burners which are fed with gas and compressed air in the case of soft glass, and where hard glass such as " Pyrex " is used,

gas and oxygen are employed. Some glasses, although harder than soft or soda glass, are not quite so hard as Pyrex, and are bent by means of burners working with gas and air, and a trace of oxygen mixed with the air.

In the washing department is a large lead-lined tank where the tubes are washed with dilute acid and rinsed with distilled water, subsequently being dried with hot air. This washing is an essential part of the processing of neon tubes, for on its correct execution depends to a large extent the quality of the colour and life of the tube.

After washing, the tube passes to the electrode bench, where two electrodes are sealed on to each tube. These electrodes consist of a cylinder of metal housed in a glass tube about 4 inches long and up to twice the diameter of the glass of the rest of the sign. The electrodes are actually the terminals of the neon tube, and transmit the electrical energy to the gas. When the electrodes are sealed on, a small length of tube open at its outer end is also sealed on and the tube is sent to the pumping-room. Here the small tube mentioned above is sealed on to the pump tube, and by a special process described later the tube is exhausted and filled with gas at a predetermined pressure, sealed off, and passed to the ageing-room. The tube remains here for some hours running at a low current, and when it is required, is taken to the testing shop for testing and transformer matching. The whole processing is carried out very carefully and under the strictest supervision, so that the tubes as they finally emerge from the factory *en route* for the site are as perfect as they can be.

The factory keeps a record of every tube made, and all layouts are carefully filed. This is done to ensure prompt and accurate duplication of any tube which may be broken during transit or fitting, or at some later stage in the life of the sign, and assists greatly the successful maintenance of the sign. Thus in the case of a sign erected, say in Glasgow, by a London firm, the maintenance man in Glasgow telegraphs or writes to say that one letter has been broken. It is not worth while to return

the broken sections, and the factory turn up their layouts and make a new tube, confident that it will fit as before. So time and expense are saved, and the owner of the sign receives maximum service at minimum cost.

## § 3. *TYPES OF NEON SIGNS*

*Signs for Outside Use.*—Practically any design can now be reproduced in luminous tubes, and artists engaged on this work are given almost unrestricted licence in producing original designs for their clients.

All that has been attempted with filament lamps can now be executed with neon, and in addition the continuity of line with the sharp, clear-cut incisiveness which can be obtained with neon, establishes these signs definitely in the forefront of illuminative publicity. The displacement of neon from the position it has so far attained will take much ingenuity of thought on the part of chemical and electrical engineers, particularly as this medium is daily gaining increasing popularity and entrenching itself in the minds of both the user and the public. Neon has come to stay, and the day is not far distant when ordinary filament lighting will largely have ceased to exist for outside publicity except in a secondary capacity.

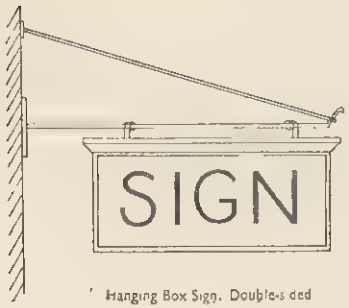
Possibly the simplest form that the outside sign can take is the single or double sided box. This box, which usually contains the transformer, is supplied as a more or less self-contained unit. The neon tubing is mounted to either wooden or metal panels, and the letters are given " body " by sign-writing on the panels. The erection of these signs is quite a simple matter, and may easily be undertaken by the handy shopkeeper. A bracket, which is supplied with the sign, is fixed to the outside wall by means of three or more Rawlplugs and screws ; and the box, the top of which is fitted with two hooks, is merely hooked over the cross-bar of the bracket so that it projects at right angles to the face of the building, and can thus in

the case of the double-sided sign, be seen from both up and down the street. When the shopkeeper does not wish to interfere with his facia and requires a simple attractive sign which can readily be dismantled in the case of removal to new premises, a box sign is, perhaps, the ideal. The wiring from the meter is very easy, and can readily be undertaken by either the shopkeeper or handy electrical man.

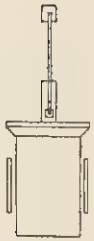
A more ambitious scheme can be carried out with the facia, when the neon sign usually takes the form of the name of the business or owner. In this case it is customary to mount the tubing to background letters and thence either direct to the facia, or first to an iron frame and then to the facia. The simplest type of facia sign employs the frame, and this frame is fixed at about four or six points. Apart from a coat of paint or varnish the facia usually need not be disturbed unless it is of glass, when a special frame must be provided so that it can be fixed to the wall above and below the glass, as the risk of breakage due to drilling a glass facia in position is rather great.

A very elaborate facia can be made if the old facia is stripped off and a new one erected. This procedure is not advised unless the whole shop-front is being rebuilt, when the shopfitter and the sign-man should collaborate to devise the ideal job. The new facia may be of black glass of either ornamental or plain shape, and having its edges finished off with a strip of stainless steel or chromium-plated brass. The background letters for the neon tubing would also be of stainless steel or chromium plated brass, and fixed direct to the glass so that no supporting clips or screws would be seen. The faces of these letters—the thickness or projection from the facia being about 3 or 4 inches—would probably be slotted so that the tubing could rest half in and half out of these slots. In such a case, the transformers and the whole of the wiring would be concealed behind the facia, provision for this being made by the shopfitter.

This type of sign is becoming increasingly popular, as



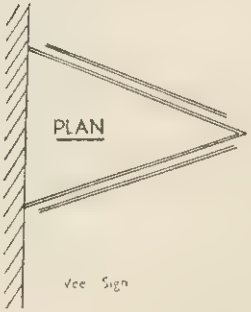

Hanging Box Sign. Double-sided



Vertica Sign.

FIG. I.

Showing three types of simple Neon Sign for outside use. The box sign may be either single or double sided, whilst the "Vee" Sign is nearly always double-sided. Vertical Signs are usually single-sided unless they are of the box variety, when the Box Sign remarks apply.




Vee Sign

there is no doubt that based on the present position occupied by neon signs it is one of the most effective. If it is not desired to remake the facia, the old one being in good condition, metal letters as described above can be used and holes drilled in the facia so that the wiring, etc., can be brought out from the back. In cases where the existing facia is of glass with modern design of lettering engraved at the back, a good method of neonising the facia is to outline the whole of it with a strip of neon tubing.

It often happens that the height of the facia from the ground is comparatively low, or that it is obstructed by some other buildings, in which case a neon facia would be a waste of money. An adaptation of the facia sign, however, can be fitted to the wall, either directly above the facia proper or at any convenient height above it, care being taken, of course, to see that the light from the sign will not interfere with persons whose windows the sign may cross. Here the general layout of the sign may be as for the facia, with the exception that for signs other than facia signs iron supporting frames are almost invariably used.

If the shop or premises it is desired to advertise are situated in a comparatively quiet street off a main thoroughfare, a flat facia or facia-type sign will not be very effective. These remarks apply also to premises situated in main streets near a cross-roads, and where it is desired to catch the eye of traffic which normally would not pass the premises. Here it is necessary for the sign to project at an angle to the face of the building, and this sign may be either single or double sided ; that is to say, it may face either one way only or both ways of the street. A choice may be made between signs reading vertically and those reading horizontally. In the case of the vertical sign, if traffic from both directions is to be attracted, one sign may be fitted at one side of the building facing up the street, and another at the other side facing down the street. If, however, it is desired not to make two separate signs, both sides may be built together as one unit and erected at any position on the building according to the

conditions governing its erection. If a horizontal rather than vertical arrangement is preferred, it is usual to make the sign in the form of a " V," the width at the base being decided by the size of the sign and the projection permitted by the local by-laws. If possible, the " V "-shaped space between the sign frame and the wall should be filled in to cover up the wiring, etc. The covering-in material may be of Uralite or Masonite or some such composite sheeting. Holes must be drilled in this covering to allow for drainage of water, etc. A more efficient method consists of covering in both the top and the bottom of the " V," the covers being detachable for access to the sign equipment.

Whilst on the subject of vertical signs, remember that the design of these requires careful consideration. Do not entertain a vertical sign if the proposed wording is of such a length as will make the reading of the subject-matter difficult. It will be found that the word " CAFE," although possessing only four letters, when erected vertically letter over letter, will look like so many Chinese characters, particularly if the accent over the " E " is included. Try it and see for yourself. The particular characters involved must be given serious attention when considering a vertical sign, as a word or name commencing with a letter " I," for example, is very difficult to read.

It is a mistake also to space the letters of vertical signs in the same way as those of horizontal signs. Horizontally the letters are easily readable, continuity is maintained and the words flow. With vertical signs one mentally reads each letter *horizontally* and the mind's eye runs down the words so as to form continuity and sense. Letters should, therefore, be as near together as possible. The bottom of one letter may even touch the top of the next letter without detracting from its " readability "—to coin a new word—which cannot be said for horizontally placed letters.

All this may seem like a lecture on " Letters, their design and spacing, and their relation to vertical signs."

It is not intended to be, but it is as well to bear these observations in mind when planning neon signs.

In vertical signs avoid the incorporation of initials complete with full stops, such as J. S. BROWN, or such names as D'ARCY or DE HAAN. The setter-out will flounder and wonder where to put the apostrophe after the " D " in D'Arcy or the small " e " in the " De " of De Haan, and he will probably get round one problem by placing the small " e " horizontally after the " D," then continuing the remaining letters vertically as in other words. By doing this the public are expected to be plastic-necked, first to read horizontally and then vertically. They have not the time nor the patience to bother with the advertisement if it is going to worry them at all. The sign must first appeal, and then be easy to read and grasp.

A very simple and at the same time effective display can be made by outlining the building with either single or multi-coloured strips of neon tubing. They can be utilised to illuminate an existing facia or other type of sign, or by the judicious placing of the tubes the whole architecture of the building may be altered when the tubes are alight. In some cases two shops or buildings may be in use by one firm, and the outline of these two shops may not be continuous. By fitting neon tubing, however, the two dissimilar buildings can be made to look like one modern building when the sign is alight, and all at a slight cost.

A very popular Continental method of illumination is the installation of clusters of neon tubes without any backing whatsoever. These tubes are usually erected over the roof, and during the day when they are not alight they cannot be seen. When they are lighted, however, the whole building is transformed, and in addition a valuable landmark which is visible for miles around is provided.

There are many ways in which neon can be adapted for outside advertising and illumination, and even the most apparently fantastic schemes can be successfully carried out.

In the case of new buildings where neon is contemplated, after preparing a rough idea of the type of sign or illumination, it is advisable to let the architect and the sign-man work together on the scheme. Neon requires a special technique, and this is the study of the sign-man, even as the building layout is the study of the architect.

## § 4. *INTERCHANGEABLE LETTERS FOR OUTSIDE SIGNS*

A type of outside sign that is receiving increasing attention is that which incorporates interchangeable letters. Somewhat naturally, the biggest demand for this type of sign comes from the theatre and the cinema, where programmes and consequently advertising matter are constantly changing. The system employed is quite simple, and the whole sign can be remade in a very short space of time. A network of iron rails is fixed across the proposed site of the sign, and the letters and words are built up on these rails. *Each letter is an entirely separate unit*, and can be changed at will. A very simple hook type fixing is employed so that whole lines can be altered very rapidly. These signs are usually supplied on a contract basis, the manufacturer contracting to supply the necessary letters and effect the changes as and when required. In this way the user is provided with a permanent sign which is kept in perfect order without any trouble to himself.

## § 5. *DOUBLE AND SINGLE OUTLINE LETTERS*

The most common type of neon sign using backing letters to support the tubes have only a single line of tubing along the centre line of the face of the backing letter. Such letters are known as single-outline letters, whilst those which have tubing following all round the edge of the letters are known as double-outline.

Double-outlining is best left alone when the height of the letter is below 18 inches, except in special circumstances where a more brilliant effect is required for particular wording in a prominent position. An example of this may be seen on the facia of a well-known men's wear store in the Strand, London, the letters of which are about 12 inches high and in close double-outline, block formation. The tubes are red and of 11/12 mm. diameter, and the effect is quite brilliant. The facia is a long narrow one, and something out of the ordinary was needed here. The focal view is limited, and the sole advertising value confines itself to the public passing within a radius of fifty yards of the shop. This, of course, is an exceptional illustration. Double-outline letters serve a great number of useful purposes, and have many advantages—and many pitfalls. If recently you had travelled along Maida Vale, London, you would have been confronted by a large sign advertising a popular journal. The letters appeared to be about 4 to 5 feet in height—it is difficult to judge the height of letters when they are erected some 60 feet up—and were built up with double-outline tubes glowing red. The sign had a focal view of at least a quarter of a mile, yet it could not be read from a distance greater than two hundred yards of it. It was smudgy, blurred, and there was an excess of glare. Here was a case of a double-outline sign being not only wasteful but defeating its object, namely, advertisement. Bearing in mind that a focal view of a quarter of a mile was available, the letters should have been of such size and arrangement that the advertising matter could have been read, and probably it would have been more effective and certainly more economical to have used single-outline letters.

The author views these faults with a more critical eye than the layman, and whilst ever ready to appreciate and praise a good neon installation, deplores the manner in which signs are "sold" to the uninitiated, however cautious the said uninitiated may be. Do not spoil your art—and art it undoubtedly is—for the sake of selling a few

more feet of tubing. The result of your sale is expressed in permanent form on the buyer's building to be either admired or condemned. If the latter, it stands as a permanent indictment of the folly of permitting a temporary rapaciousness to overshadow the opportunity of achieving a fine piece of craftsmanship, beneficial to the customer and eventually yourself.

(This digression is prompted by the fact that neon salesmen endeavour so frequently to persuade the customer to install much more tubing on a given site than the site will conveniently carry. It often follows that single outline would have been much more legible and less costly.)

A walk along the main thoroughfares of most large towns in England will bring you face to face with 3-feet or 4-feet stainless steel letters having a double outline of neon tubing recessed into the face of the letters. These are fixed to the faces of numerous branches of a well-known shoe store. Here is an example of the ideal use of double-outline letters. True, the angle of view is comparatively short, limited to the pavement opposite and perhaps a few hundred feet on either side of the shop. But there is LIFE in the sign. As the steel letters have return edges of 4 inches, one can read the message clearly even at an angle of 45 degrees, and a brilliant show is obtained.

Double outline in script is rarely indulged in, as script is sufficiently difficult to read quickly without imposing the additional strain of reading double outline.

## § 6. *COLOUR AND DIAMETER OF TUBING FOR OUTSIDE SIGNS*

The colour and diameter of the tubes greatly affect the range from which the sign can be read, and these points must, therefore, receive some attention. The three most popular colours used at the present time for outdoor use are RED, GREEN and BLUE, red being the most popular of the three.

Luminous discharge tubes can be made theoretically in almost any size, but practically from 9 mm. to 30 mm. in diameter. So that they may supply glass tubing at commercial prices glass manufacturers ask for a tolerance of 1/2 mm. on the diameter. Hence we speak of 11/12 mm. and 14/15 mm. and so on, these dimensions referring to the outside diameter of the tubing.

Costs, of course, vary with the diameter as well as with colour. Concerning manufacturer's charges (by manufacturers we mean neon tube makers) to the basic charges for red and blue tubes—usually the same price—there is generally added 10 per cent. for green to allow for the increased cost of canary or amber glass, 25 to 33 per cent. for white, gold and yellow, and 20 per cent. for other shades. These are approximate figures differing slightly with each manufacturer, and do not take into consideration the additional transformer costs necessary in the case of the white and gold tubes requiring a very high voltage, or the slight reduction of costs in the case of blue tubes, which require a lesser voltage and have fewer transformers.

Although the majority of neon signs employ the three well-known colours, red, blue and green, and in some instances the pinky-white light of helium, it is, of course, possible, provided price and time are of secondary consequence, to obtain a number of delicate shades from the glass tube manufacturer which, when internally illuminated either by the red of neon, the blue of argon-mercury, or the pinky-white of helium, will emit delicate pastel shades according to the combination used. The total light emitted is comparatively small, and these tubes are primarily for local application and for viewing at close range.

The additional charges outlined above combine to increase the ultimate cost to the consumer, who invariably concerns himself with keeping costs down to a minimum. The tendency at the present time may be summed up in so many words : " What sort of a show can I get for so

much ? " and the customer is bent on getting as much " show "—expressed in terms of footage of tubing -as is possible for a given expenditure.

Much care and thought should be brought to bear in preparing schemes for submission to the client. It is as easy to erect a display with real artistic appeal as it is to erect one lacking in these qualities—remembering that " A thing of beauty . . ." One cannot blame the tube manufacturer. He is more of a physicist than an artist. His job is to make tubes to a given layout.

Avoid the simple form of layout such as " JOHN JONES " in plain block letters surrounded by a plain rectangular border. Whilst the customer may want his name expressed in neon and surrounded by a border, it is up to the sign-man to supply it with " finish." Stylish letters surrounded by an artistic border cost little more and enhance the building on which they are placed.

It is good practice to use 11/12 mm. tubing for letters below 12 inches in height, and 14/15 mm. above it. It is a scientific axiom that the *wider* the stroke of the letters of a sign that has to be used in the daytime, the greater its legibility and focal range. But the reverse applies to signs for purposes of night publicity. The *narrower* the illuminated strip of light the greater the legibility, with consequently a greater distance from which the wording can be clearly read, good range being one of the main objectives of the sign.

Below 5 inches in height, 9/10 mm. tubing is used, and in very exceptional cases where particularly fine stroked tubes are insisted upon or made necessary by the characteristics of the sign, tubing of 5/6 mm. may be used.

This tubing is, however, very fragile, and should be used only for interior signs made up in short sections as a precautionary measure against breaking, unless handled with very great care. Further, the life of this small tubing is comparatively short unless the sections of glass are

abnormally long, but this makes them very fragile as well as introducing difficulties in processing.

The use of green or blue tubing involves an entirely different ruling. It is generally accepted that for penetrative power combined with great luminosity red takes first place, with green following, and subsequently blue, this latter being by far the weakest of the three main luminous tube colours. When green is required for facia letters, tubes of large diameter should be used. For 3-inch to 12-inch letters 11/12 mm. is advisable for green, and for larger letters 14/15 mm. serves the required purpose. These larger tubes are necessary with green in order that the strokes of the letters may have " body," a property which is reduced by using small diameter tubes with large letters, due to the reduced area of light around the tubes.

The light from blue tubing is very weak when compared with the other colours, and for this reason the tubes should be of a diameter equal to that advised for green, with the exception that blue tubes over 2 feet 6 inches in height should be made of 18 mm. tubing. This size would appear at first glance to be abnormally large in diameter for use with letters, but it is advised if the job is to be done efficiently and effectively.

The foregoing points are the result of experience in the use of different-sized tubes in conjunction with different colours, and can be used with confidence in the specifications of neon signs.

Tubes for double-outline lettering should not exceed 14/15 mm. in diameter even for letters 8 feet in height. Although tubing of 20/22 mm. actually gives more light, just as it consumes more current, and its flood-lighting and local effect are increased, its legibility from a distance is considerably decreased. This is due to irradiation or what we call " blur." There is only one way by which an increased quantity of light may be projected from an individual letter whilst retaining its legibility. That is by having all the tubing sunk well below the sides of the trough forming the shape of the letter.

In letters of this size—8 feet—the parallel strokes should be spaced at not more than 6 to 8 inches apart. If it is desired that the space between the strokes be illuminated, more tubing may be introduced between the outline strokes of the letters as a " filling-in " of the same or a contrasting colour. An example of triple-outline lettering may be seen in Oxford Street, London, on the facia of a well-known furnishing store, where the central line is red and the outlines are green.

A more expensive and elaborate method of " filling-in " the space between the outer strikes is by using tubes placed zigzag fashion across the blank space, and these tubes may again be in contrasting colours. The result of this method is very attractive when viewed from close range, but from a distance the effect is lost, as the outer lines " kill " the central tubing.

Certain manufacturers of tubes are able to produce, in addition to red, blue and green, a variety of other colours such as yellow, gold, pearl, ivory-white, lilac, mauve, etc., and various refined shades which are at once novel and attractive. These colours are used in special instances where an artistic combination is desired and expense is not of primary importance, but from a commercial viewpoint, red, green and blue are the most successful.

There is a unique type of letter imposed on the face of a West End theatre at St. Giles Circus, London. This letter is in " single-outline " block, with square corners, *complete with its casting shadow*. The main stroke is in blue, and the " shadow " stroke in red. The effect is very striking and is an advance on any other type of letter extant, as it gives the appearance of possessing a third dimension, *depth*, without using any extra tubing.

## § 7. *EXTENT OF ILLUMINATION FROM NEON*

It cannot be too strongly emphasised that luminous discharge tubes, whilst in themselves extremely legible owing to their large distributed surface of low intensity

light—that is, relatively low intrinsic brilliancy—do not diffuse much light on surrounding objects in the same way as would a flood-light, which is a focused light. If a quantity of neon tubing using 500 watts could be concentrated and condensed to practically a pinhead and placed in the focal point of a good reflector, it would have equal flood-lighting value. But this is impossible, because 500 watts would be the consumption of practically 70 feet of normal sized tubing, and it is obvious that its light could not be condensed and concentrated to the extent that the spiralled tungsten filament of a 500-watt lamp can be. For this reason one should not expect to fully illuminate and flood-light a surface of a building by simply running some border tubing around its outer edges. Here the source of light and not the light itself is important. With neon tubes we are dependent more upon the source of light, whereas with filament lamps it is the light which counts.

## § 8. *THE EFFECT OF FOG ON NEON*

Red light is universally used as a danger signal because red rays of light have great penetrating power through fog, dust and smoke. The penetrative power of red light varies as the twelfth power of the wave-length, and as the light emitted from the red end of the spectrum is of low frequency and consequently of long wave-length, the twelfth power of this length is a very considerable factor and places it at the head of the list of values in light penetration.

Neon is no better than ordinary lamps with red screens in front of them, but is very much more efficient because practically all the electrical energy expended in a neon tube results in the emission of red rays, whereas in an electric lamp or other light source with a red colour screen, all the light-rays other than the red are cut out and wasted by the screen and only the red ones passed. For this reason it is finding increasing favour for use in indicating

aerodromes, lighthouses, towers and other land and sea marks, as well as accounting for its great efficiency and legibility at a distance as a sign.

## § 9. *THE USE OF OPAL TUBING*

There are two or three sorts of glass that can be classed under opal or opalescent. First of all, there is the plain white opal, then the 3-ply tube, consisting of a layer of clear glass inside and outside with, sandwiched between it, a very thin layer of white enamel glass. There is also the so-called fluoride glass, which is very similar to the modern pearl-finished electric lamp.

The use of opal glass tubing for neon signs is not nearly so extensive as is that of clear glass, and it is used almost exclusively for interior illumination. The reason for this is that the glow is not so intense as with clear glass, and whilst this is a disadvantage for outside use it is a decided advantage for inside use. Opal glass has the very pleasing effect of softening or diffusing the glow, and when used around a room or a window produces a warming effect. Opal glass is used also for window display signs of the portable self-contained type, and the soft delicate shades produced are very attractive.

Opal glass tubing is used for outside signs where it is desired to produce a diffuse glow, for reasons either of interference with people nearby or in accordance with the particular scheme of illumination. In narrow streets where a clear glass sign would throw too great a glow in the roadway to the confusion of traffic, and would also interfere with shops on the opposite side of the street, opal glass may be used with success, and as long range is not the main object, the general appearance of the sign will be considerably improved over a clear glass sign. Script letters in opal tubing on black facias, without backgrounds, are very effective both by day and night.

The effect in daylight is also very good, as the white

opal tubing stands out very clearly against the black background.

Where neon is employed for exposed interior lighting – that is, where it is not concealed behind rails or friezes – opal glass is almost invariably used. Neon is not, however, successful as a primary illuminant, but where used in conjunction with filament lighting, this latter being possibly indirect, very beautiful effects can be attained. A ceiling, for instance, may be flood-lit by hidden filament lights, whilst a neon candelabra hangs centrally into the hall or room. The pendant may be of any number of colours, and to vary the effect each separate colour may be controlled by a separate switch so that it may be switched on or off at will, producing a rainbow effect.

## § 10. *MULTI-COLOUR TUBES*

Charming colour effects can be obtained by joining together sections of different coloured glass and filling with one gas. Thus a piece of opal glass joined to a piece of amber glass and filled with helium produces a tube half-white and half-gold. Similarly blue and green, blue and white, red and white, red, white and blue, etc., may be obtained in one section of tubing. This is a very valuable property for copying well-known designs, as any shade can be reproduced and the shades remain permanent.

## § 11. *REGULATIONS REGARDING THE FIXING OF OUTSIDE NEON SIGNS*

Generally speaking, the regulations pertaining to the fixing of exterior signs in London are more rigid than those outside London. The London County Council Sign by-laws state that the maximum vertical depth of a sign shall not exceed 2 feet 6 inches, the projection from the building line 4 feet—provided, nevertheless, that there shall be at least 2 feet 6 inches between the outside edge

of the sign and the carriage-way—and the horizontal length of the sign 2 feet. The distance between the public footpath and the underside of the sign must not be less than 8 feet. An alternative set of dimensions is : Vertical depth, 2 feet 6 inches as before, projection 2 feet, and the horizontal length 6 feet. If the proposed sign conforms to these sizes, it is necessary only to give notice of erection to the local authority, such notice being given seven clear days before the sign is to be erected. If the sign is of larger dimensions, then it is necessary to apply to the L.C.C. for a dispensation of the by-laws in respect of perhaps only one or all of the dimensions. A linen drawing and two blue prints must be submitted, and it is usual for a month to elapse before the result of the application is known. The local authorities have no power to dispense with the L.C.C. regulations, but if the latter body agree to a sign normally outside the allowed dimensions, then the local people are notified and the sign-erector gives the seven days' notice in the usual way.

When a sign is in the L.C.C. area, and whether or not it is necessary to obtain permission from the L.C.C. even if the sign is being erected over a private forecourt, there is one official to whom notice must be given seven days before the start of the erection of such a sign on the requisite blue form prescribed by the London Building Act. This individual is the District Surveyor for the district in which the sign is to be erected, and who is the inspector for the L.C.C. under the London Building Act. He is usually an architect who gives part or whole time to his duties, which are primarily to see that the plans are passed, or that dispensation granted by the L.C.C. is carried out or complied with and not exceeded. His prime duty is to make sure that all structures are safe and that fixings are mechanically strong, or that buildings are able to withstand the thrust or pull of supports or brackets.

This official, if treated courteously, can be of great assistance and often tenders useful skilled advice as to how difficulties may be overcome. When the job is

finished he supplies you with another blue form which it is incumbent upon you to fill up, and wherein you make a declaration as to the value of the work carried out. The sign firm is defined as the " builder " from the time the first form is filled up, and they and not the customer are held responsible for any fees or damage or breach of the regulations. Upon the receipt of this second blue form (which has to be sent direct to the District Surveyor) he will make an assessment for his fee based upon a sliding and *ad valorem* scale prescribed under the London Building Act. The builders are held liable for this fee, as already stated above. It should be noted in passing that the estimate usually submitted to the customer states that the price quoted for the sign does not include any surveyors' fees which may require to be paid in connection with its erection.

It has been held that under the L.C.C. Building Act it is not permissible to fix even a small enamelled iron plate to the wall of a building situated well inside its own grounds without first notifying the District Surveyor. (*Note.*—Do not confuse the District Surveyor under the London Building Act with the Surveyor from the Local Authorities.)

The L.C.C. are prepared to allow signs up to 50 feet in length, but they are rather strict about the vertical depth. They are not prepared to grant dispensation of the by-laws for signs over 2 feet 6 inches in vertical depth. The L.C.C. grant permission for the erection of signs subject to the electrical installation being in accordance with the requirements of the L.C.C. Fire Brigade (Inspection Department) and the recommendations of the Institution of Electrical Engineers. An emergency switch, popularly known as a Fireman's Switch, must be fixed on the outside of the building at a height of approximately 8 feet 6 inches from the ground with the " OFF " position on top, so that in the event of a fire the sign may readily be switched off.

The Low Tension wiring, *i.e.* the wiring from the meter room to the sign, must be run in screwed conduit

when on the outside of the building, and the High Tension wiring must be run in tested and approved lead-covered cable. The series wiring between the sections of tubing comprising the sign must be protected by sleeving of glass or other incombustible material, and the supporting clips must adequately support the neon tubes. Where a sign is fixed outside licensed premises, such as a restaurant, dance hall, etc., the Fire Brigade insist on minor refinements to further ensure that there is no chance of any unauthorised person tampering with the sign and receiving a shock. These refinements consist in covering all cable connections with glass insulators or " Bell Glasses," in painting high tension cables *red*, in padlocking or sealing transformers, and in fixing suitable notices warning persons coming near to the sign that a high voltage is present. These notices must also be fixed on the outside of the building to prevent accident to window cleaners, etc.

The various authorities in the suburbs of London and the Provinces have different regulations regarding the erection of neon signs, but it is generally conceded that those of the L.C.C. are most exacting. In some cases it is necessary to run lead-covered high tension cable in an armoured duct or provide some alternative form of additional protection, whilst in other cases there is hardly any limit to the size of the sign. With all signs where any doubt exists as to the possible attitude of the local authorities, it is wise to consult them first.

It should be borne in mind that the afore-mentioned dimensions relating to signs within the area controlled by the L.C.C. apply to signs which project beyond the building line, *i.e.* over the public footpath. Where the proposed sign is behind the building line, *i.e.* it is on the property of the owner or tenant of the building, then the L.C.C. have no jurisdiction over the sign apart from general structural considerations, and the size is almost unlimited. If, however, it is desired to fix a sign advertising a commodity or product not made by the person or firm on whose building

it is proposed to erect the sign, then the building is considered by the L.C.C. to be an advertising hoarding, and their approval must first be obtained.

Sky signs, *i.e.* signs through the interstices of which it is possible to see the sky, are governed by the SKY SIGN ACT of the County of London, and are not permitted in London. The sky must not be used as a sign "background," and in cases where the sign is to be fixed, say, on the top of a parapet wall where there is no building to back it, sheet metal or some other backing must be provided. In any case the height *above* the parapet or highest point of the building is limited to 3 feet maximum. (*Note.*—Railway companies' property is exempt from this proviso.)

Outside London, sky signs seem to be more or less generally permitted, and a journey along the Great West Road will show how well this type of neon sign looks. One notable example of the sky sign is to be seen at the Heston Air Port. This consists of the monogram of the firm which owns the airport, Messrs. Airwork, and the initials "A.W." are arranged so that they are the same from the front and back. The sign is a double-outline neon sign, with the tubing arranged along the edges of the letters, and is controlled from a flasher so that it flashes the aerodrome signal. This is an exceptional case, where the sign is used perhaps more as a beacon than a sign, and if it were in London the authorities would probably pass it.

Flashing signs are not encouraged in London unless they are of the spelling type.

## § 12. *WHAT TYPE OF ELECTRIC SUPPLY IS NECESSARY?*

We have seen that neon signs will operate only from a high voltage and that this voltage is obtained by transforming the mains supply voltage of perhaps 200 to about 10,000. As a general rule direct or continuous current cannot be transformed to a higher voltage unless it first be

converted to alternating current, and where the only supply available is D.C. it is necessary to instal a machine known as a Rotary Converter. This machine, the size of which depends upon the size of the sign, is installed in any desired and convenient position and may be controlled by either a hand starter or automatic contactor control.

## § 13. *CURRENT CONSUMPTION*

The low current consumption of neon tubes is one of the many points in its favour. Neon tubes run practically cold, which fact means that nearly the whole of the current consumed is transformed into light and very little wasted by being transformed into heat. With the filament lamp the reverse is the case. These lights run hot, and whilst they gave a brilliant light, about 95 per cent. of the current is dissipated in the form of heat, the remaining 5 per cent. being all that is left to serve the purpose of the bulb or lamp, namely, the dissipation of light.

Whilst neon tubes, as has been shown, require a very high voltage for their operation, the amperage or current is very low. The following figures give some indication of the amperage of the three most commonly used sizes of tube. They are based on red tubing (which passes slightly less than green or blue).

11/12 mm. tubing passes approximately ·025 amperes, that is, 25 milliamperes.

14/15 mm. tubing passes approximately ·035 amperes, that is, 35 milliamperes.

19/21 mm. tubing passes approximately ·060 amperes, that is, 60 milliamperes.

The term " approximately " has been used as the figures are not hypercritical but tend to vary according to the various manufacturers and their (the tubes') general characteristics. The number of electrodes has a considerable bearing on the current consumption, for the reason that the voltage drop per pair of electrodes has no

relation to the voltage required per foot of tubing. For example, forty 12-inch letters would require 120 feet of tubing—based on the calculation of single-outline letters requiring three times their height in footage—as would twenty 24-inch letters. If the letters in each case were made with two electrodes per letter, then the current consumption of the 12-inch letter sign would be more than that of the 24-inch letter sign, for the reason that the latter would have twenty electrodes less than the former.

There is in use amongst sign-makers a fairly precise method of calculating the current consumption of any sign. This is as follows :

One foot of 11/12 mm. red neon tubing requires approximately 160 volts for its satisfactory operation, and one pair of electrodes requires a voltage of 280. It is usual to provide where possible one pair of electrodes for every 10 feet of tubing, so that 10 feet of tubing requires ten times 160, equals 1600 plus 280, equals 1880 volts.

Current consumption is expressed in watts, and the number of watts is calculated by multiplying the current by the voltage. From the above table we see that 11/12 mm. tubing requires or consumes ·025 amperes, an ampere being the unit of current, so that to obtain the wattage of our 10 feet of tubing we must multiply the volts 1880 by the amperes (or amps.) ·025. This gives us a wattage figure of 47 for 10 feet of tubing, or 4·7 watts per foot. As one (Board of Trade) unit equals 1000 watt-hours, a sign having twelve 12-inch letters of 11/12 mm. red neon tubing—36 feet in all—would consume 169 watts or ·169 units per hour. If the price per unit of electricity is 4d. then the cost of running the sign is less than 1d. per hour.

It has been mentioned that it is usual to provide one pair of electrodes for every 10 feet of tubing. In some cases, however, the consumer may insist on each 12-inch letter being a separate unit, *i.e.* a pair of electrodes per letter.

A rough-and-ready method of calculating the voltage drop is to consider each electrode as being equivalent in

this respect to one foot of tubing, so that our separate 12-inch letter has a voltage drop equal to 5 feet of tubing. This will mean that with a sign having twelve separate 12-inch letters of 11/12 mm. red tubing the equivalent footage will be 60 feet, voltage required, 9600, and current consumption 240 watts or ·24 of a unit per hour.

The actual footage of this sign, based on three times the height of the letters, is 36 feet, so that our current consumption is now 240 ÷ 36, or $6\frac{2}{3}$ watts per foot. Thus it is advisable to keep the number of electrodes per sign as low as possible.

## § 14. *CONSUMPTION OF NEON COMPARED WITH BULB SIGNS*

With bulb signs having letters up to about 3 feet in height, it is usual to install 15-watt bulbs, and these bulbs are so spaced that a nearly continuous line of light is obtained. Naturally, the closer the bulbs the nearer will the result be to the desired effect, but in practice it is more or less the rule to space the bulbs about 3 inches from centre to centre. In the previous chapter the current consumption of a sign having twelve 12-inch letters was considered, the letters being of neon. With a bulb sign, there are on an average seven bulbs per 12-inch letter, so that for a twelve-letter sign there would be 84 bulbs. If each bulb consumed 15 watts, the total consumption of the sign would be 84 × 15, equals 1260 watts. The consumption of the neon sign was 169 watts, or just under *one-seventh* of that of the bulb sign ! With electricity costing 4d. per unit, the neon sign would save 6d. per hour, and if the sign were in operation for six hours per day for six days per week, the total saving in current alone for the year would be £46. 16s., a sum which exceeds the cost of the neon sign.

Taken for all sizes of letters and tubes, it is found that neon consumes only one-sixth of the current consumed by a bulb sign. In addition to this, the legibility of neon is

considerably greater than that of bulbs, and also the neon shows a continuous line, whereas the bulbs show a broken or dotted line.

A brief calculation of a proposed sign, bearing in mind the above figures, will show that, in nearly every case, a neon sign will pay for itself in current saved, in approximately one year.

## § 15. *BACKING MATERIALS*

(1) *Masonite Presdwood.*—This is a grainless board, uniformly smooth of surface and entirely free from flaws and knots. It is manufactured from exploded wood fibre, and compressed into boards $\frac{1}{8}$ inch and $\frac{3}{16}$ inch thick, 4 feet wide and up to 12 feet in length.

There is nothing but wood in its composition, and no chemicals are used in binding the fibres, as the lignines reunite as in nature, resulting in a board stronger than ordinary timber of similar thickness, of great weather-resisting capacity, and adaptable to most of the requirements of the sign-maker.

Being an all-wood product, Masonite Presdwood can be handled and worked by the same methods used for timber. It can be sawn, drilled, sanded, planed and bevelled and fixed with glue, nails or screws as desired. It is particularly useful for cutouts and carved signs. Its grainless character and toughness permit shaping and bending without risk of splitting, and a smooth unbroken surface as large as 12 feet by 4 feet, if necessary, is provided without a joint.

For outdoor signs Masonite may be confidently recommended for its resistance to water and variable climatic conditions. It does not blister, crack, corrode or rust. For neon signs Tempered Presdwood only should be used, as this is more capable of meeting the requirements. Masonite is non-fire-resisting.

*Note.*—Uncrate twenty-four hours before use and stack to allow for acclimatisation to take place. Prime the

back and all edges to prevent possible shrinking and warpage.

(2) *Plymax Panels.*—Plymax panelling is used frequently in conjunction with neon installations. This material is made of plywood faced with metal on one or both sides, and is exceptionally weather-resisting.

When deciding on a background it is essential to remember that warping and shrinking are fatal to neon tubes, as they would crack under the strain. Consequently only materials possessing those qualities likely to withstand the rigours of our climate will suffice.

It is essential, therefore, as soon as the order for the sign is obtained, that instructions are forwarded to the panel-maker for execution.

Panels should be ordered cut to size and with sealed edges. The sealing of the edges should be specified, as this protects the plymax against the ingress of water and moisture generally. The panels can be smartened up with wooden or other beading according to individual taste and condition of service.

The electrode holes can be bored in the workshop or on the job. If requested, the makers will specially treat the surface of the panels for painting.

Paint the panels in the usual manner on the face side, and also the back, as a protection against weather.

Protect the electrode holes with white lead or paraffin wax melted into the raw edges of the plywood by a hot soldering-iron. A further protection consists of bushing the holes with metal.

(3) *Teak.*—Local laws demand that teak or some other hardwood be used as a background for neon tube letters. This insistence on the part of our " big-wigs " is a wise one.

In atmospheres laden with sulphurous fumes such as London's, and in some of the industrial towns of the North, metal letters suffer rapid corrosion and are far outlasted by teak.

The writer is aware of certain teak letters exposed in London to all weather conditions, that are now over thirty years old and " still going strong."

A word of warning, however. There has been a tendency recently to call certain African more-or-less hardwoods, " teak."

They are much cheaper than the genuine Burmese teak, but their felling and seasoning, etc., are not so carefully regulated as in Burma, from whence the best teak emanates, and where everything connected with its maturity is rigorously controlled by the Forestry Department.

The recent attempt to introduce African " teak " for neon sign purposes is one that should be discouraged. A comparison of the relative weights of Burmese and African teaks shows that the latter is much lighter and consequently far less dense. Being more open-grained it is, therefore, more porous and absorbent, thus exposing itself to shrinking and swelling.

Genuine Burmese teak is one of the most fireproof and weather-resisting of woods, and least likely to shrink and cause damage to the tubes.

With these material advantages in its favour, teak has been universally adopted for use with neon signs, and the action of the authorities in demanding its use is to be lauded. It is, in effect, a safeguard for the purchaser, the general public and the maker of the sign. All are happy and the teak merchants are even happier, having found a new and increasing market for their wares in an otherwise restricted field of sale.

Note in conclusion : Teak letters must be at least 1 inch thick—in some districts 2 inches.

## § 16. *MAKING AND INSTALLING A NEON SIGN*

The following guide to installation has been prepared with a view to assisting in carrying out a complete neon sign throughout its various stages, beginning with ordering

the tubes, right through to its logical conclusion—switching on and seeing it light up.

The style of the characters and their method of application to the particular site need not be rigidly adhered to, but are merely examples which could with safety be employed when erecting a neon sign. The making and installing of the sign present no real difficulties if due care and attention be paid to the following details.

It is assumed in the first instance that the general specification and text of the sign have been decided upon, and that the permission of the Local Authorities or the L.C.C. has been obtained, if this is necessary.

For the purpose of explanation, a sign reading JOHN BROWN in 18-inch letters will be considered, and the general specification is that the sign shall be erected on the brickwork of the building between the first and second floor windows.

The colour of the tubing will be red, of single outline, and the background letters will be of teak, finished with red cellulose. The framework will consist of two parallel iron runners, with arms grouted into the brickwork.

The first job of the sign-man—unless this has already been done for the preparation of the L.C.C. blue prints—is to carefully measure the proposed site, paying due care to windows, drain pipes, and other projections and obstructions. A scale drawing should then be prepared, showing the sign in position, and from this scale drawing the full-size layout of the background letters may be made. The regulations demand that background letters, if of timber, shall be made of teak or other hardwood, and it is recommended that teak only be used, and of about 1 inch to $1\frac{1}{4}$ inches in thickness. With the sign under discussion, each letter would be made as a separate unit, *i.e.* two electrodes would be fitted to each letter, and these electrodes would project at right angles to the tubing and pass through holes in the wood letters. The diameter of the tubing would be 14/15 mm. and that of the electrodes

$\frac{3}{4}$ of an inch, so that the diameter of the holes to be drilled in the teak letters should be $1\frac{1}{8}$ inches.

Send a copy of the wood letter drawings to the tube-maker, making sure that the positions of the electrode holes are clearly marked, and that the distance between the wall and the sign is indicated. In stating this, reference should be made to the drawing of the building, so that if one or more electrodes coincide with drainpipes or other projections there will be sufficient clearance. Give the tube-maker details regarding the colour and diameter of the required tubes, and state if they are to be single or double outline letters.

The boring of the electrode holes in the wood letters may be deferred until the tube-maker sends back the

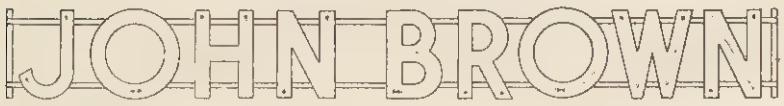



FIG. 2.

Scale layout of John Brown sign showing the background letters fixed to the iron frame. The neon tubes are shown dotted.

layout, when he will indicate both the positions and diameter of the electrodes.

When the background letters have been made, the ironwork should receive attention. This is to consist of two parallel members running the length of the sign, and for rigidity, angle-iron 1 inch by 1 inch section will be found quite suitable. The distance between the runners must be such that the electrodes are not obstructed, and if the wood letters are laid face downwards on the floor in their proper relationship, the runners may be put on top and their positions marked. Bracing members should be bolted across the runners, as it is bad practice to allow the wood letters to take the strain, and " U "-shaped arms for grouting into the brickwork and to which the runners are bolted should be made. Screw on the wood letters.

When the tubes arrive from the tube-maker, they should be tested and transformers matched to them. In some cases the tube-maker will supply the transformers, in which event he will match them, but, generally, it is cheaper for the sign-erector to match his own. A rough idea of the number of transformers is first obtained from considerations of the layout of the sign, and the footage involved. In the sign under discussion, there are nine 18-inch letters, and from previous chapters we find that each letter will take about 4 feet 6 inches of tubing. This makes a total footage of 40 feet 6 inches, or 18 feet for "JOHN" and 22 feet 6 inches for "BROWN." As 40-odd feet is too much to run comfortably off one transformer, two will be required, one for each part of the name. In selecting the transformers, the tubes are connected in series on the test bench, and a transformer joined in circuit. In the secondary circuit, and in series with the tubing, connect a milliamp-meter, and after connecting the mains supply to the primary, the current may be switched on. The milliamps should not exceed 35 for 14/15 mm. tubing, and if the transformer is of the adjustable type, it may be adjusted to give this reading. When the desired effect is obtained, carefully label the transformer, and repeat the performance with the other sections.

The tubes are now ready for mounting, and they should first be tried in the electrode holes to see that they are correctly made and that the requisite clearance has been provided.

Check the alignment of the tubing and the wood letters and see that they register correctly, after which mark the wood letters for the tube-supporting clips. An 18-inch letter would require three or four clips to support the tubing, and it is essential that these supports be so arranged that no strain is imposed in any direction on the glass tubing. Remember that glass tubing is very brittle, and that it cannot be "stretched" when cold. Try to get a support onto a horizontal portion of the letter—if any—

to prevent the tube slipping down and resting the electrode on the wood letter or perhaps the ironwork.

Tubing supports are made of glass or phosphor bronze. The former consist of a cup-shaped section of solid glass which has been melted onto a piece of threaded brass rod, the ends of the glass having been turned over so that a retaining wire may be fixed around it and the tube. Bronze clips are more generally used. They are similar in appearance to rubber stamp clips, and are shaped so that the tube goes in with a " click " and the springiness of the bronze retains it in position. They are bolted to the top end of a short length of threaded brass rod or " studding," and this is pushed through a hole in the wood letter and held in position by two nuts and washers. The height of the clip above the surface of the letter depends upon the number of " double-backs " of the neon tubing, and should be chosen so that there is about $\frac{1}{4}$-inch clearance between the wood letter surface and any glasswork. The whole of the letters should be carefully checked to see that the projection of the tubing is the same in each case, otherwise the appearance of the sign will be seriously impaired.

Having assembled the sign, its erection is the next consideration. Until quite recently it was the practice to remove the tubes after they had been assembled, leaving only the glass supports in position. The skeleton sign and framework were then fixed to the site, and the glass remounted. This practice is somewhat slower than that in which the whole sign is erected together, but it is to be recommended where there is any danger of breaking the tubes through the " unhandiness " of the sign or difficulties in erection. Where facilities for fixing-tackle exist, and where there are no projections likely to foul the sign during hauling, the complete assembly may be erected at once, leaving only the high tension wiring to be carried out. Whether this is practicable in any particular case depends, of course, upon the site, facilities for the erection of tackle, size of sign and rigidity of sign and framework.

The method of erecting the framework and wood

letters to the building need not be discussed here. This is a straightforward proceeding, and does not differ from the erection of an ordinary sign. Make certain that the " U "-shaped arms are embedded well into the wall, and that a sufficient clearance between the wall and the sign is provided, to ensure electrode clearance and also to facilitate access being had to the connections in the event of a breakdown.

(1) *Position for Transformers.*—Before mounting the tubing onto the wood letters, the transformers should be positioned. The choice of site depends upon a number of factors. The ideal position is where the distance between the sign and the transformers is not more than 6 feet, but this cannot always be achieved. The best plan is to locate for each transformer its ideal position, and then ask the owner of the building, or the client for whom the sign is being erected, if he will agree to those positions. Usually, he will want them put somewhere out of sight, in which case they must be tucked around some corner, resting preferably on a ledge or canopy. Bear in mind, however, the nearer they are to the sign, the more efficiently they will operate, and further, do not position them in some obscure corner so that they cannot readily be got at. Local site conditions vary so much, that it is almost impossible to give here any indication of the best transformer positions, but if they are arranged so that they are close to the sign, and, at the same time, may easily be got at, then there is little wrong with their installation.

It has already been arranged that there shall be two transformers for the sign JOHN BROWN, one for JOHN and one for BROWN, and these transformers have been matched to the tubing and labelled accordingly. We will assume that there is a stone ledge running along the building, about 12 inches above the sign, and that this ledge is of sufficient width to safely accommodate the transformers. We will therefore mount them here, one above the centre of the word JOHN and the other above

the centre of the word BROWN. Fix them securely to the wall by either bolting a strap around them, or by means of lugs welded to their cases, but see that when they are fixed it is possible to take the lids off and work inside the transformers.

(2) *Mounting the Glass.*—The sign is now erected, and the transformers are in position, so that the mounting of the glass is the next consideration. This is a small matter, as the actual fitting has been done in the shop, and all that remains is to fix the tubes into the clips already positioned. It is, however, this part of the job which is responsible for the highest percentage of breakages, and, as has previously been pointed out, glass is not elastic but extremely brittle. One golden rule to observe is, do not be nervous in handling the glass tubes. Nervous and delicate handling, or touchiness, will result in more tubes being broken than are erected in position, and whilst care in handling is obviously necessary, a firm touch also is essential. This comes readily with practice, and the sign-erector who does not break a few tubes when he starts erecting neon signs is not normal. When fitting the tubes into the clips, see that the positions of the latter have not been altered during the erection, otherwise the glass will be strained in trying to fit the tubes. When they are pushed home there should be a slight suggestion of play, and this may be tested by gently tapping the tube near the supporting clips, when a rattle should result showing that there is not undue tightness. This should not be taken to mean that the tubes should be a sloppy fit in their clips ; in fact, each tube should be wired to its clip with a small length of bare wire such as fuse wire, twisted around the tube and the clip. In fitting the tubes the height of the supports should first be checked to see that they all project equally from the face of the background letter. If they do not, when the tube is pushed home, it will mean that part of the tube is out of line with the other and a strain will be induced.

It is somewhat difficult to line the bronze type of sup-

port correctly, and this is one advantage of the glass type. Here the tubing may be rested on the supports and they can be adjusted correctly to the exact form of the tubing before it is wired on. This is an important point, and many inexperienced sign-erectors account for broken tubes with the excuse that the glass was improperly annealed, whereas actually the supports had been incorrectly adjusted.

(3) *High Tension Wiring.*—The sign having been erected and the transformers positioned, all is ready for

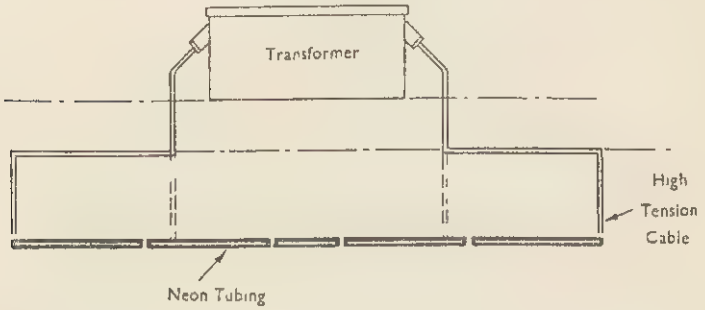



FIG. 3.

This diagram shows how the high tension cable should be run from the transformer to the tubing. Note the transformer is standing on the window-ledge, and the cable follows the underside of this ledge, so that it is obscured as far as possible. The dotted lines show an alternative method of running the cable, where part of the run is hidden behind the tubing.

the high tension wiring. Deal first with the "JOHN" transformer. Cut off two lengths of lead-covered high tension cable, one to reach from the first transformer secondary terminal to the first electrode of the "J," and the other to reach from the second secondary terminal to the last electrode of the "N." In measuring the length of these cables, allowance should be made for the cables to come out of the transformer, extend vertically downwards to the sign, and then horizontally along to their correct positions. This is shown in the sketch (Fig. 3), and it will be noted that it is a great improvement in

appearance over the sign where the cables take the shortest path between transformer and electrodes. The cable ends must be prepared strictly in accordance with the instructions outlined on pages 46 and 47.

As this sign is being erected outside, and consequently subject to all conditions of weather such as rain, snow, wind, etc., the electrodes to which the high tension cables are connected must be well protected to prevent rain dripping on them and so conducting the current, *via* the lead covering of the high tension cable, to earth. This would undoubtedly put the sign out and may, in addition, cause a fire. The high tension cable electrodes are termed Terminal electrodes, and for their general protection insulating glasses should be used. These glasses are about 4 to 6 inches in length and are constructed with two legs, one of larger diameter to pass over the tail-piece of the high tension cable. In some cases the two legs are at right angles to each other, whilst in others they are arranged parallel, according to the particular nature of the job. Fig. 4 shows three types of insulating glass, and these may be considered as standard, with possible slight modifications. The high tension or Cable glass is used for protecting the ends of the lead-covered high tension cable, and affords an incombustible covering to the taping applied to the cable.

The Bell glass is used for protecting the electrodes where they are doubled back behind, and parallel to, the tubing.

The Pipe glass serves a similar purpose to the Bell glass, but is used where the electrodes project at right angles to the tubing. In the case of our JOHN BROWN sign, pipe glasses are correct.

For wiring the terminal electrodes, first connect the cables to the transformer terminals ; the other end of each cable should terminate in a small loop, and to this loop there should be securely twisted a short length of bare nickel wire. Thread this wire through the wide end of an H.T. glass, and then pass the latter over the end of

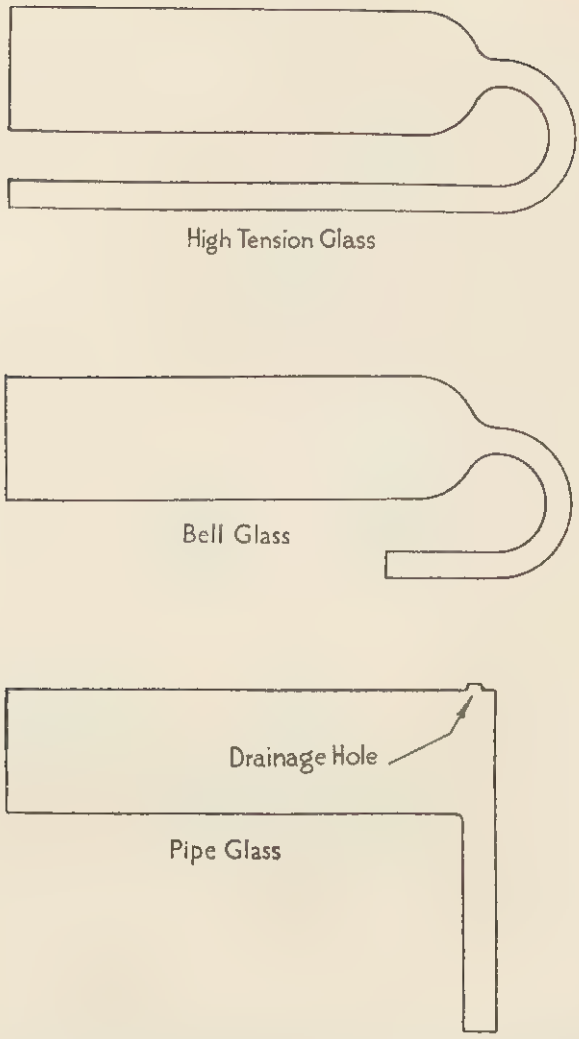



FIG. 4.

This shows the types of insulating glasses in use. The high tension glass is used to protect the ends of the high tension cable, the bell glass is used to protect parallel electrodes, and the pipe glass is used to protect electrodes which project at right angles to the tubing. Note the drainage hole in the pipe glass to allow rain-water to escape.

the lead-covered cable, so that the bare wire projects from the thinner leg.

This bare wire should now be passed through the small end of a pipe glass, threaded through it, and out at the

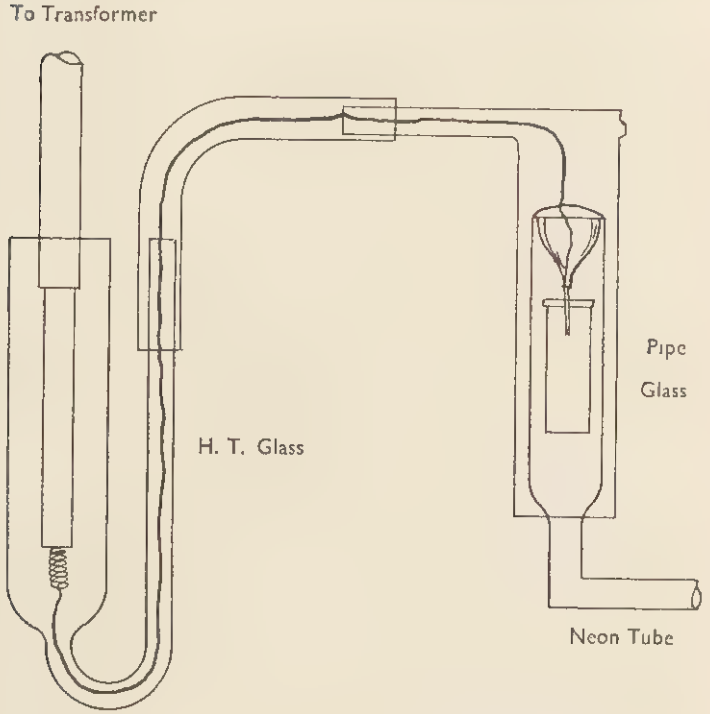



FIG. 5.

This illustration shows the complete connection between cable and electrode. The electrode is protected by means of a pipe glass, whilst a high tension glass protects the cable. The short curved length of tubing between the two glasses serves to connect up the whole, and fully cover the wire. In this diagram the cable has been shown diagrammatically, without tape, etc.

wide end. There are now two glasses threaded on the end of a piece of bare wire, and the free end of this wire should be securely twisted to the connection of the particular electrode which is being dealt with. When a good connection is made, gently ease the wide leg of the pipe glass

over the electrode, thus completing the wiring of one electrode. The diagram Fig. 5 shows how the finished connection should appear, and the performance should be repeated for the remaining terminal electrodes. It may be found convenient to introduce a short length of small diameter glass tubing over the bare nickel wire and between the high tension glass and pipe glass. The diameter of this tubing should be such that it will fit either inside or outside the small legs of the two insulating glasses, and so will provide a complete covering to the wire even though the glasses be moved in relation to each other.

The electrodes between the terminal electrodes are known as Series Electrodes. They are the electrodes between the " J " and " N " of " JOHN," and the " B " and " N " of " BROWN." These are wired together—the electrodes of " JOHN " being, of course, separate from those of " BROWN "—in *series*, and for this purpose bare nickel wire may be used, provided, of course, that there is no possibility of this being reached or touched by hand, or of it blowing in the wind and making contact with the wall or ironwork or other earthed parts. It is advisable to use pipe glasses over the electrodes, and small diameter glass tubing over the bare wire connections from electrode to electrode. In this way there is little danger from accidental touching or from the wind blowing the wires, and although it takes a little longer to carry out, the extra time will be well repaid.

The sign is now completely wired, and if the low tension wiring contractor has done his job correctly, there should be a pair of low tension cables close to each transformer. Before touching these cables, remove the fuses from the distribution board and put them in some position where they cannot be touched or replaced by some well-meaning person not working on the sign. Give them to the electrician who is carrying out the wiring, and thus preclude the possibility of the current being switched on whilst he is working on the sign. Connect the low tension

cables to the primary terminals of the transformers and check over all connections to earth and tubing. See that all metal parts are bonded together and connected to earth, and that all contacts are tight. Replace the fuses controlling the sign "JOHN," and try switching on the current for an instant. If it appears to be burning properly, switch off, withdraw the fuses, and connect a milliamp-meter in the secondary circuit. Switch on again after having replaced the fuses, see that the milliamps are correct, remove the meter, and repeat the performance with the circuit "BROWN." If this is in order, the whole sign may be left alight.

In some cases it may be found that whereas in the workshop the sign functioned perfectly, when the transformers are connected outside and the sign is erected on the building there will be a flicker in the tubes when the current is switched on. This may be due to the voltage in the shop not agreeing with that on the site, and to test this a voltmeter should be connected in the low tension circuit, and the tappings on the transformers altered if necessary, to suit the reading. Most transformers are provided with a tapped primary coil so that any voltage between 200/250 may be used, and where it happens that a slight flickering develops, this can sometimes be remedied by altering the primary tappings. Care should be taken, however, to see that the transformer overload, if any, is not more than about 5 per cent. Thus, if the actual mains voltage is 240 and the sign flickers, an attempt to remedy the defect by connecting to the 230-volt tapping on the transformer is quite permissible.

Where a long run of high tension cable is unavoidable it will sometimes be found that the characteristics of the tubing when in the workshop will not be the same as when the sign is in position, due to the effects of the cable. To offset this, the adjustable magnetic leak provided on the transformer will usually be quite effective, failing which the tappings on the transformer will have to be altered to suit the new conditions.

Variation of supply voltage is one of the most irritating causes of trouble in installing a new sign ; hence the need for carrying a low tension voltmeter. In addition, an ammeter should be carried and connected in the low tension circuit. When the tubes are switched on, the ammeter reading should be taken and compared with that marked on the name-plate of the transformer, as an increase of this indicated current will cause the transformer to overheat and in time burn out.

In dealing with the erection of a neon sign, it is necessary to emphasise one very important rule which must be strictly adhered to. That is, before any work is done on or in connection with the high tension side of the installation, remove the fuses and give them into the charge of the wireman who is working on the sign. This rule will be fully appreciated when it is realised that the voltage is in the region of ten thousand, and that with some forms of trouble when the current is switched on there is no response, as far as glow is concerned, from the sign. In these circumstances the wireman may be tempted to seek the defect without first switching off, unless he has been instructed with regard to the withdrawal of the fuses, when the feel of them in his pocket will assure him that the sign is " dead."

## § 17. *PREPARATION OF HIGH TENSION CABLE ENDS*

The successful operation of a neon sign over a long period is largely dependent upon the care exercised during the installation of the sign, and in this connection the preparation of the ends of the high tension cable is of paramount importance. Most high tension cable used for external neon signs is of the lead-covered variety, and is about $\frac{5}{8}$ inch in diameter. The lead covering is approximately $\frac{3}{32}$ of an inch thick, and the necessity for care in preparing the ends of such a cable will be appreciated from the fact that the outer or lead covering is connected

to earth, and the high tension current passes along the wire in the centre. The centre of the transformer secondary winding is also connected to earth, so that between the conductor and its outer sheath, *i.e.* the lead covering and the central wire, there is a potential difference of about 5000 volts. Thus if the two " poles " are not well insulated from each other, there will be a tendency to sparking across.

The first step in the preparation consists in marking off a length of from 5 to 6 inches of the cable from the end, and stripping off the lead covering—and armouring, if any—from this portion. The stripping must be carried out with care, and the lead scored instead of cut. This precludes any possibility of the rubber insulation, which lies almost directly underneath the lead, being cut. If a deep score is made all round the cable, it will be found that by bending it a few times the lead covering will readily break, when it may be pulled of. If the rubber is covered with a linen tape under the lead, this also should be removed, after which the copper conductor should be exposed for a distance of about 2 inches from the end. Here again care must be exercised in removing the rubber, so that the conductor is not cut or nicked. The conductor end should be bent to form a loop of approximately $\frac{1}{2}$ inch in diameter, to facilitate making the connection between the cable and the electrode, and the cable is then ready for " doping."

The first stage in doping consists in applying a coat of " Pakyderm " insulating varnish over the whole of the exposed section of rubber, including the section where the conductor emerges, and also to the edges of the lead covering, so that there is little danger of moisture getting between the lead and the rubber, or between the rubber and the conductor. A roll of bitumen impregnated, or " Bitumastic " tape about 1 inch in width, should now be wound in spiral form around the cable end, starting from a distance of 4 inches along the lead covering from the exposed rubber, and ending up about 3 inches from the

outer end of the rubber, thus covering an area of approximately 6 to 7 inches. Having bound with one layer of tape, repeat the whole performance, *i.e.* first apply a coat of varnish, allow it to dry, and retape. Make sure that a liberal supply of varnish is applied to the cut ends of the tape, to prevent water being soaked up by the cotton of which the tape is partly composed.

If the open circuit voltage of the transformers for which the cable is required is high, use as many as four to six layers of tape, varnishing between each layer, and finally applying an additional coat to the last layer. It is important that the preparation of the ends of high tension cables be carried out under dry conditions, and under no circumstances must they be carried out in the rain.

## § 18. "*EARTH RETURN*" *HIGH TENSION WIRING*

In the example of the sign "JOHN BROWN," the high tension wiring was carried out on the two-wire system, *i.e.* one cable from one terminal of the transformer extended to one end of the tubing, and from the other end a cable returned to the second terminal of the transformer.

This system is quite suitable for small signs such as has been discussed, but in large installations where hundreds of tubes are used the "earth return" system of wiring may be employed to advantage. Briefly, this means that one terminal of the transformer will be connected to earth, one electrode of the tubing will also be connected to earth, and the circuit completed by connecting the other electrode to the second terminal of the transformer. This is illustrated in Fig. 6, and the advantage to be gained will readily be appreciated. On installations where there are large quantities of border tubing, the earth return system saves a considerable length of high tension cable, and as this costs in the region of 1s. 6d. per yard, the saving will be appreciable. In

addition, there is less "potential" trouble through having less cable.

We have seen that a 10,000-volt transformer will operate about 40 feet of tubing, if necessary, so that in an outlining installation using, for example, 120 feet of tubing three transformers will be required. This means that if the two-wire system is employed, about 45 feet of high tension cable will have to be used for each transformer,

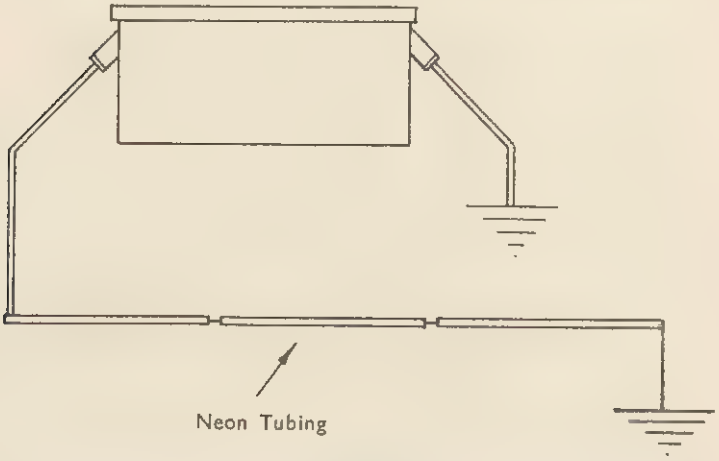



FIG. 6.

This is the simple form of the earth-return system of Neon Sign wiring. In the diagram a length of cable has been shown extending from the transformer to earth. This has been done merely for explanatory purposes, and in practice one leg of the high tension side is connected to the transformer case, which is then earthed.

making a total of 45 yards for the whole sign. If, however, the earth-return system is used, the length of cable can be reduced to about 4 feet for each transformer, thus saving about 40 yards on the whole job. The transformers would be positioned at the ends of their respective 40-foot sections of tubing, and a short length of cable would connect one end of the tube to one terminal. The other terminal and the other end of the tube would be connected to earth and the circuit so completed.

The installation here described, using 10,000-volt transformers, would have a maximum earth potential of 10,000 volts, and the transformers would have to be of the type in which the centre point of the secondary is not connected to earth *via* the transformer case. Usually the authorities insist that the maximum earth potential shall not exceed 5000 volts, in which case a modified circuit as shown in Fig. 7 would have to be used. Centre-tapped

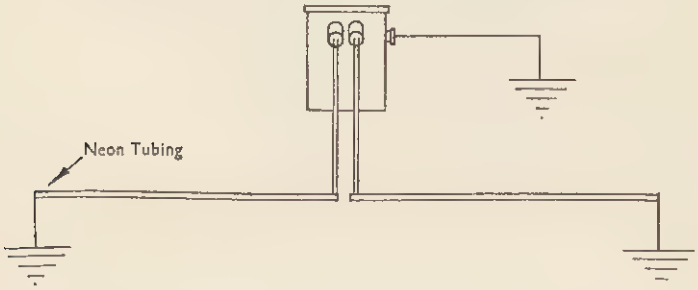



FIG. 7.

This is the circuit which must be used where earth-return is employed and an open circuit transformer voltage of more than 5000 is used. Fig. 6 showed the simple system where one leg of the high tension side is connected to earth, and in that case the size of the transformer was not more than 5000 volts. Most sign makers use 10,000 volt instruments, in which case in order that the sign may conform to the regulations, which state that the maximum open circuit voltage to earth must not exceed 5000, the above circuit is used.

secondary transformers would be used, and the centre point in each case connected to earth, whilst the transformers would be positioned at the centre of each tubing circuit.

## § 19. *MAKING AND ERECTING A BOX SIGN*

Neon box signs are one of the most popular types of signs in use. They are cheap, and provide a maximum amount of advertising for a minimum outlay, and are, therefore, greatly favoured by the small man and the multiple shopkeeper who wishes to confine his advertising expenditure within fairly small limits.

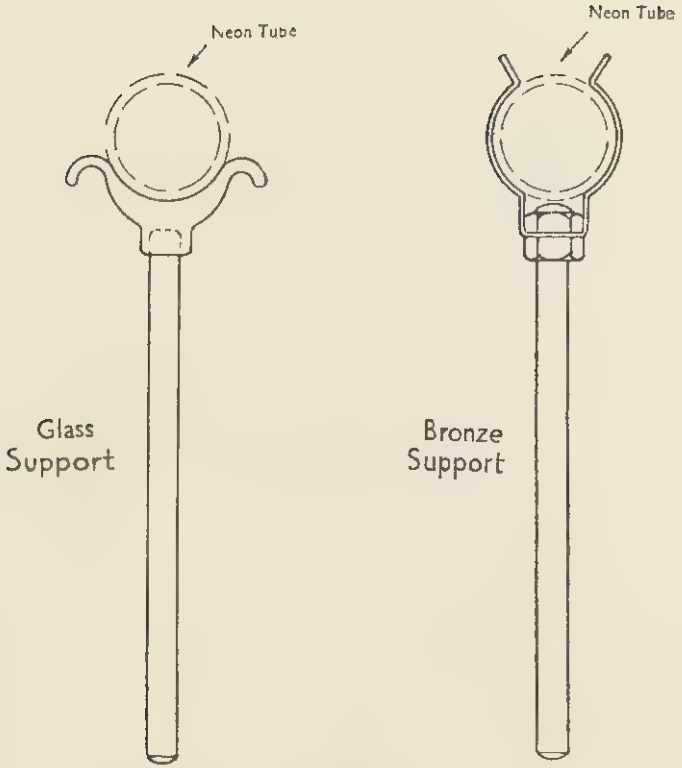



FIG. 8.

Showing two types of Neon tube support. In each case brass threaded rod is used, and for the glass support, solid glass is melted onto the end of the rod and shaped as shown. The supports are held in position by means of two nuts.

Exterior box signs are usually made of lead-coated sheet metal, with panels of either metal, wood, Masonite or Plymax. The tubes are fixed to these panels in much the same way as with ordinary teak letter signs, and the panels are drilled to take the clips and the electrodes. The type of clip used is either glass or phosphor bronze, as illustrated in Fig. 8.

In designing the box provision must be made for easy access to the electrodes for wiring the transformers, and it is usual to provide a door at each end of the box. These doors should be as large as possible, and may, in fact, cover the whole of the ends, protection from the rain being afforded by a small hood at the top. In addition—or alternative—to the end doors, *part* of the bottom may be hinged, the remainder being required for supporting the transformers.

In the case of a double-sided box sign, see that the depth or thickness of the box is sufficient to provide ample clearance between the electrodes from one side and those from the other. The usual depth is 8 inches from panel to panel. Before drilling the electrode holes, two tracings of the suggested positions should be made and laid back to back. This is the relative position in which the two sides will be erected, and the trial allows the draughtsman to see that the holes on one side do not coincide with those on the other side.

If the daylight appearance of the sign—*i.e.* when the tubes are not alight—is not important, then it will be found quite in order to mount the tubes directly to the panels without backing letters. If, however, a daylight sign is required, an effective appearance is produced by painting the wording or design on the panels. If the tubes are red, then the colour of the sign writing may be a deep chrome with vermillion or white edges, and it will be found that these colours assist the night effect of the sign. The background may be a dull black.

A good night effect is secured by painting the whole of the background with a matt black. This has no day

effect, and at night it assumes a detached appearance, neither assisting nor hindering the red glow from the tubes. One Company after numerous experiments found that the colour combination having the greatest visibility and advertising value is bright yellow for the letters and dark brown for the background. During the day the bright colours make the sign very attractive, and at night the tubes stand out in flaming lines against an intensely black background.

As an alternative to the sign-written panel, the text may be made in the form of wood or other material letters fixed to the panels, and having the tubes fixed to the letters. This is a more expensive form of sign, and is generally used only on buildings where any other type of sign would not look suitable or would be disallowed.

The wording of a box sign is more or less limited, due to the regulations which state that the size shall not exceed 4 feet in projection by 2 feet 6 inches in height. In some cases even these sizes are not permitted, so that the wording or text becomes of necessity smaller. Over private grounds the size may, of course, be increased.

Six- to eight-inch letters are the largest that can, in general, be comfortably employed, and they should not be unduly elongated or the visibility of the sign will be impaired. Four or five of these letters are usually joined together in one section of tubing, the connecting pieces between letters being blacked out with dull black paint. Should wood or metal letters be used as a background, then it will be found advisable, from considerations of appearance, to provide each letter with a pair of electrodes, thus making each a separate section. This is a costly business and involves more wiring and larger transformers: the latter increase, of course, being necessitated by the greater number of electrodes.

Another and attractive method of mounting tubes to box signs is with the aid of stencilled or fret-cut panels, in which slots a little wider than the diameter of the tubes

are cut, and the tubes semi-recessed into these slots from either the back or the front of the panels. It is, however, usual to fix the tubes from the back, due to the fact that very wide slots would have to be cut to allow the electrodes to pass through from the front, and also the connecting tubing between the letters would be exposed. Where the rear mounting is used, the connecting pieces are set behind the remainder of the tubes, so that the letters may rest in the slots. The tubes are held in position by means of thin wire tied around bridge pieces crossing the slots at intervals. A further method is to solder " L "-shaped pieces of metal to the back of the panel, and to these fix the usual type of supporting clip.

Often the transformers may be mounted inside the box, and if this can be arranged it provides a self-contained unit. The whole of the wiring is enclosed and protected from the rain, and in case of breakdown, the tubes and transformers are all grouped closely together, thus facilitating maintenance.

The box sign and the casing of the transformer should be earthed to prevent the possibility of shocks in the case of a leak. To assist in maintaining neon box signs in a clean condition, glass panels may be fitted about 1 inch in front of the tubes. These shelter the tubes from dust and rain, and make for easy cleaning of the sign. The glass panel has the additional advantage that it helps to keep the sign waterproof, by preventing water from being blown in through the electrode holes. Whilst the box should be rainproof as far as possible, ventilation holes should nevertheless be provided to allow of the free passage of air and the escape of any water which may have collected in the bottom of the box. A few small holes drilled in the base will effect sufficient ventilation and drainage.

The sign can be suspended from a wrought-iron bracket fixed at right angles to the wall, the erection of which is the same as for ordinary signs.

## § 20. *GLASS PANEL WINDOW SIGNS*

Prepare a full size layout of the tubes to be manufactured, forward it to the tube-maker, and he will return it indicating where the electrodes will project through the panel and also the positions of the clips necessary to hold the tubes in place.

The preparation of the layout for the glass panel manufacturer may then be proceeded with, and this should indicate clearly the size of each hole to be drilled. Show also positions of holes for suspension chain shackles and rosettes. There are sometimes thirty to forty holes in one large panel, and great care is needed by the plate-glass manufacturer in carrying out this work, as a false boring is liable to crack the glass.

When the panel is returned correctly drilled, it is ready to take the tubing. A glass panel, particularly if it is large, is a rather difficult article to handle, and to facilitate the mounting of the tubes the panel may be temporarily suspended above the bench. This permits the tubing-fixer a clear space all round his panel, so that he may work without fear of breakages.

The tube supports are fixed in their proper positions, and in passing it will usually be found that the glass crochet type of support is the neatest for glass panel signs. As with all tubing erection, the height of the supports must be carefully adjusted before they are tightened, so that no strain will be imposed on the tubing when it is fixed in position.

The tubing may now be fitted and wired to the supports. In some cases it will be found more efficient to mount the tubing to the panel in the shop and transport the job *en bloc* to the site, whilst in others the better method will be to install the glass panel on the site and then fix the supports and tubing. This is a matter which the particular exigencies of the installation will decide.

## § 21. *INSTALLING THE PANEL*

The installation of a glass panel sign is slightly different to that of an ordinary sign. The first consideration should be the positioning of the transformer or transformers. These should be erected preferably so that they cannot be seen from outside the shop window, but at the same time they should not be fixed so that it becomes necessary to dismantle the window-dressing for access to them.

It is a wise precaution to enclose the transformers in a case made of some incombustible material and provided with a lock. The outside of the box should be clearly marked " Danger—High Voltage," and the key be given to some responsible person, not left in the lock. In certain districts the local authorities insist upon the enclosure of transformers in locked boxes, but in some cases it will be found that the provision of metal-cased transformers which have screwed-down lids are accepted as locked boxes, the screws rightly being considered as a locking system.

After the transformers have been installed, the ceiling plates should be fixed. Generally, these can be screwed into the ceiling quite satisfactorily. In some cases, however, the ceiling may be too high for convenience, when it will probably be found that a satisfactory job can be made by screwing the plates into the wooden cross-bar or frame at the top of the window. In passing, it may be mentioned that where a glass panel sign is to depend from a soffit over a lobby, the ceiling plates can be screwed directly into the soffit, and the transformers placed inside the building and on top of the soffit directly above the panel.

The vertical position of the panel having been decided upon, the chains can be cut to their required length and the panel suspended into position. Whilst on the subject of chains, it should be noted that the longer the chains the greater will be the tendency of the panel to swing, and where long chains are provided—as in the case of a sign being suspended from a high ceiling—it will be found that the sign is continually swinging. In addition to spoiling

the effect from an advertising point of view, if the glass tubing comes in contact with the window during its swing, breakage will probably occur. If, of course, it is impossible to employ short chains, some means should be provided for preventing the panel from swinging. This may take the form of two thin guy wires attached to the chains and extending to some convenient support ; or, the liability of damage to the tubing by swinging may be discounted by fitting rubber buffers to the bottom of the panel. The length of these buffers should, of course, be greater than the projection of the tubing from the panel.

If the panel was wired in the shop, all that now remains to be done is the running of the high tension and low tension wiring. If the tubing has to be mounted after the panel has been suspended, this operation should be carried out in the manner previously described.

The running of the high tension wiring in the case of a glass panel sign calls for some ingenuity in concealing the wires. It is quite probable, however, that one transformer will operate the whole of the tubing, and two wires only—or one wire to each chain—will thus be sufficient. With large signs, where, say, two transformers are required, the size of the panel will probably be too large to allow of only two chains being used, in which case we may still have one chain per wire.

The object of the foregoing remarks on number of wires per chain will doubtless have been appreciated. It is common practice to run the wiring down the suspension chain, which then helps to hide the wire and so make a neat installation. If it is preferred, tubes may be used instead of suspension chains. These tubes have a hook formed at each end for hooking over the ceiling plate and shackle respectively, and the high tension cable runs through the tube entering from the transformer at the top and emerging for connection to its electrode at the bottom.

It is rather more essential to shield the electrodes of a glass panel sign suspended in a shop window or lobby than is the case with an external sign. The latter is gener-

ally beyond easy reach of straying hands, whereas the former is so easy of access to window-dressers and others that it is liable to be a source of danger to them. The shielding suggested is intended as a protection against persons making accidental contact with any naked high tension wire, and takes the form of special glasses and glass tubes of sufficient bore to pass easily over the electrodes and connecting wires. If glass is not used, then insulated flex may be used for the series wiring, and specially shaped bell glasses for the electrodes in the usual way.

The use of non-glass-covered insulated flex is not recommended as, in the first place, it is unsightly, and in the second, it is not so simple to provide a well-insulated connection with this wire.

Where the sign is installed inside licensed premises, the local authorities may insist on the provision of a secondary glass panel behind the main panel. To comply with this, use 21 oz. glass, so arranged that the two panels and the high tension wiring form a sandwich, with the wiring in the middle. An alternative to this consists in fitting a wire mesh screen behind the glass panel and over the wiring and electrodes. This screen can pick up on some convenient tubing supports, and the mesh should be not more than ½ inch to prevent the accidental insertion of fingers.

The regulations governing the installation of a glass panel sign and its equipment are such that danger of fire is practically eliminated. Shop assistants should be warned against approaching the sign without first switching off, and a notice worded " Danger—High Voltage ; Switch off before entering Window," should be displayed near by.

In fact, proof of the inviolability of neon signs to cause fire is evidenced by the offer of a well-known insurance company to cover all risks including damage and destruction by fire, riot, explosion, malicious damage, storm, tempest, damage by water occasioned by burst pipes, etc., aircraft and impact by road traffic, excluding

destruction of or damage to dynamos, motor resistances, transformers, or other electrical working apparatus directly due to abnormal currents or self-ignition. Up to £10,000 in respect of legal liabilities to the general public or other third-party risks arising out of injury or damage alleged to have been caused by the sign, for as low as 10s. per £100 per annum. Of course, this liability is restricted to the cost of the sign, not the building upon which it is erected.

## § 22. *BORDERS, OUTLINE TUBES AND THEIR FIXING*

The application of the neon tube for borders and outlines is very effective, and permits of a maximum display for a minimum cost.

The architecture of the building will naturally affect the form of lining decided upon, but in some cases where the building may not be uniform or may belong to some very obscure form of architecture, then the neon tubes are able to completely transform it with a style of their own.

Take the case of a double-fronted shop of some 30 feet in extent. You are invited to recommend some strip lighting ; something not too expensive, but which will give the fullest publicity value for a limited expenditure.

Possibly the simplest, most economical and practical display here is a strip in one straight line running along the entire length of the facia, and terminating in two drops, one at each end, with a key or similar design to round off the dead ends. Such a straightforward line embraces the whole of the frontage of the shop, and tends to emphasise its size.

Peculiarly, it also appears to give height to the building, and although this sounds strange, it can readily be checked by looking at a similar installation.

Thus, this comparatively simple and cheap outline in 15 or 20 mm. tubing has done the trick, and the question

then arises, " Why spend more on the front if such a line is effective by itself? " The answer obviously is that whereas one 60-watt lamp will light a room, two 100-watt lamps will light it to greater advantage.

Whilst the strip of neon is effective, it alone is not sufficient to completely illuminate the facia. The penetrative glow of a neon tube is second to none, but the amount of light dissipated around the tube is very small, and will illuminate only in its immediate vicinity. Thus the strip would not prove sufficient to light up the facia letters, whether they are of stainless steel mounted on black glass, of ordinary wood construction, or of any other type. Similarly, bordering the whole of the facia would still not be sufficient, although naturally this would be more effective than a single strip. The solution lies in outlining the letters also, by superimposing neon tubes to their faces.

By a combination of the two, *i.e.* tubes mounted on letters together with a border, a striking effect is obtained using, preferably, contrasting colours for the letters and strip ; as, for example, red for the letters and blue or green for the border.

In a previous paragraph, 15 or 20 mm. diameter tubes were specified for the strip lighting. The reason for this is that for a single strip, extending over a span of 30 feet, a thick stroke is essential. The use of narrower tubing, 12 mm. for example, would have a paltry effect ; 12 mm. alone, even along a 10-feet facia, looks thin and is not recommended. There is a shop in Oxford Street, London, on the facia of which there is superimposed approximately 40 feet of straight 12 mm. tubes glowing green. The light by day is hardly visible, and by night only slightly better. To all intents and purposes it is not existent, and is a waste of money.

For a single strip of border it is desirable to use intense red. This colour is by far the most striking and brings the premises definitely and forcefully into prominence.

The question arises, " Why cannot one get away from

this incessant red? Are there no alternatives?" There are; but the use of any other colour for this particular job would halve the publicity value of the display. After all, the reason for strip lighting is to bring the premises into prominence, hence the use of the most penetrating colour, intense red.

If any other colour is insisted upon, green or blue or yellow, use tubing of as large a diameter as possible. The larger tube gives a greater area of light, which is, however, still less penetrating than that given out by a red tube. Thus a large blue or green tube balances a smaller red tube, and is necessary to an effective display.

A combination of colours in strip-lighting gives a charming effect to an otherwise straightforward display. Parallel lines of red and blue tubes, either straight or zig-zag, and spaced about 2 inches apart, give a mauve effect and make quite a brilliant show. Something different. Of course it doubles the cost, but where a customer is not limited to a given expenditure this can be recommended with safety, and executed with the assurance of his complete satisfaction.

The question of strip-lighting the building over the entire front is usually entertained only by cinemas, theatres and the more progressive stores. These concerns rely largely on their exterior display for attracting the public eye, and may be depended upon to spend a considerable sum on neon and allied display, both initially and yearly.

When preparing a strip-light design for any building, try to conform to the original architecture, picking out the main lines, curves and general features peculiar to the style. If this is done, the tubes when alight will create in the mind of the onlooker the real purpose of the architect's design, and he will be able to associate the lighted building at night with its unlighted form during the day. This association is valuable, as there are many buildings now illuminated which cannot be recognised by day although they are familiar at night.

Should it be undesirable to conform to the natural

architecture, the lines perhaps not lending themselves to tubular lighting, an entirely new design may be prepared and submitted.

The client having approved the scheme, the vital matter of fixing the tubing next demands consideration. The practice common to this form of lighting is to fix the border or strip-lighting tubes direct to the face of the building, without employing a background, as would be the case with letters. This practice is desirable for two reasons : first, lower costs ; and secondly—and perhaps the most important of all—greater neatness.

By day, neon tubes are not beautiful, and should be made to present a neat and unobtrusive appearance. Border work is designed primarily to show off the architectural beauty of the building—if any—at night. Its presence by day must, therefore, be hidden or obscured. The employment of backgrounds or strips of teak behind the borders would have the very reverse effect, merely emphasising the presence of unilluminated glass tubes.

In some special cases, of course, it may be *necessary* to fix tubes to a sub-background. This applies where the building face is broken up and continuity of tubes is difficult because of the lack of natural background. For example, if a customer insists upon straight lines of tubing being carried right across the face of his building fronted perhaps by two prominent bay windows having a bulge of 2 feet or so—instead of conforming to the curves of the bays, the necessity for background strips between the bays becomes apparent. Such an installation is, however, rarely called for, but may sometimes be necessary.

Ingenuity of treatment of design in relation to a particular building may with safety be left in the hands of the sign-maker with ideas—but do not take liberties with the tube manufacturer and his ability to bend tubes into fantastic shapes. There are limits—pretty wide, but still limits.

To return to the question of fixing. The first point to consider is the splitting up of the design into tubes of such

a length that they can be easily and economically handled. To facilitate this, a scale drawing of the building should be prepared. A convenient length for straight tubes is 7 feet 6 inches, and when these are being marked off on the scale drawing, a gap of $\frac{1}{4}$ inch should be allowed between adjacent sections. To avoid difficulties in measuring, the gap may be split up between the tubes thus : divide the plan into 7 feet 6 inch sections without gaps, and make the tubes 7 feet $5\frac{7}{8}$ inches. For mounting the tubes to the building it is usual to employ ⌐⌐ -shaped bridges made up from $\frac{1}{2}$ inch by $\frac{1}{8}$ inch brass strip. These can be made up in large quantities for stock purposes, and should be standardised. They are drilled with three holes -two for fixing to the wall, and the other to take the tube support.

The normal type of tube support fixed to a screwed brass rod is used, and is adjustable for height. Three supports should be allotted to each length of tube, and these should be spaced one in the centre and one about 9 inches in from each end of the tube.

The general details of fixing the tubes to the supports have already been discussed, and care should be exercised to see that no strain is imposed on the glass by unequal projection of the supports, and also that the sections of tube give the appearance of a continuous unbroken line. The gap between sections appears non-existent when the tubes are alight.

Consideration should be given to the electrodes. For strip-lighting, electrodes are invariably doubled back parallel with and behind the tube proper, as illustrated in Fig. 9, so that from the front they cannot be seen. The glass wall of the electrode, when doubled back, should have a clearance of at least $\frac{3}{8}$ inch from the tube. This is to allow bell glasses to be fitted and to give these a reasonable clearance.

Insulating glasses should be used on all exposed electrodes, as is the practice with exterior lettered signs.

With a desire to reduce to a minimum the prominence

of the electrodes, as their presence breaks up the evenness or continuity of the borders, a good practice is to completely box them in, so ensuring watertight and fool-proof connections. This is, however, not absolutely essential and is rather costly.

Having erected the tubes and seen that they are in perfect alignment vertically and particularly *horizontally*, it now remains to fix the transformers and run the high tension cable to the electrodes, as in other forms of neon installations.

The position of the transformers is important. It is inadvisable for various reasons to run too long a length of high tension cable between the transformers and the electrodes: primarily, because every foot of cable con-

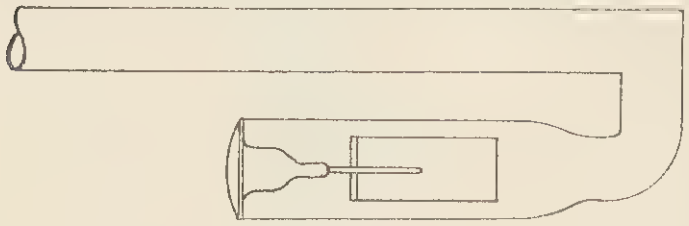


FIG. 9.
The parallel type of electrode.

ducting the high tension current from the transformers to the electrodes is responsible for a certain potential drop *en route*. In other words, should the output from a 10,000-volt transformer be required to pass through a 50-foot length of cable to reach the electrodes, a voltage of *less* than 10,000 would actually get there. Where, however, the high tension run does not exceed 5 to 6 feet, only a very small loss is entailed. Make every effort to avoid long runs of lead-covered high tension cable, keeping below 12 feet of such cable in a circuit if possible.

A further reason for the avoidance of long lengths of cable is, its lead sheathing acts as a condenser and is liable, under certain conditions, to produce resonance in the circuit, with unfavourable results. Consideration must,

therefore, be given to this very important aspect of the neon installation. (See Section on "Earth Return.")

When wiring the high tension cable, see that it runs in lines either parallel or at right angles to the tubing. This makes for a neat and workmanlike installation, and is so much better than allowing the cable to take the shortest path between transformer and electrode, irrespective of their relative positions.

An interesting point here is that border or striplight runs can easily be fed by the transformer high tension cables from some middle point, feeding left and right with an equal amount of tubing on either side. Generally, however, the positions for the transformers are decided by considerations of accessibility, and the wiring must be run accordingly.

The series wiring between sections can now be carried out, and for this work bare nickel wire threaded through glass tubes will be found most effective, the electrodes, of course, being protected by bell glasses into the small diameter legs of which the series tubing should telescope.

Some municipal and electric supply authorities insist that all high tension cable must be protected by hard metal covering, or run in screwed steel conduit, and will not pass unprotected lead-sheathed cables. It is not the intention to discourse academically on whether high tension cable should or should not be enclosed in conduit, but it has been proved that this enclosure gives rise to undesirable effects, and in fact it has been disallowed by the I.E.E. Its main purpose was the protection of the lead covering, but this is now effected by using armoured cable or by enclosing it in troughing.

The high tension wiring from the transformers to the tubes has now been carried out. Naturally, on a large installation the transformers will be spread all over the building, each transformer being as near as possible to its particular circuit. Where practicable, group together as many transformers as possible—on the roof if the tubes

are to be run nearby—as this serves two purposes, namely :

(1) They are out of sight, thereby ensuring a clean job.
(2) The low tension leads will be carried to one part of the building instead of several, and costs reduced thereby.

When the whole of the wiring is completed, connect up the supply and take current readings. If, after test, everything is O.K., the installation is ready for service.

## § 23. *CONVERSION OF TROUGH-LETTER SIGNS TO NEON*

The sign-man is often called upon to undertake the conversion of an existing trough-letter bulb sign to neon, and to this end a brief survey of the method to adopt will perhaps not be out of place.

First remove the lamps—to avoid breakage—and store these in some suitable place, for they may come in useful for another job. Dismount the letters from the framework, take them to the workshop, and remove the wiring and lampholders from them. We now have a trough letter with its background perforated like a Meccano strip, and the next step is to either plug the holes or, a more efficient process, to cut out from sheet steel a new background the same shape and size as that existing, and fit this new background to the old " perforated " one. It can be retained in position by soldering from the back of the letters. It will probably be found that the existing fixing clips can be used again, and if this is the case little remains to be done except repainting and drilling for electrodes and supporting clips.

It is advisable to entirely remove the old paint from the letters before repainting, and this stripping may be done before or after the new background is put in. The outside of the letters should be painted or sprayed with a colour to

match that of the tubing, whilst the inside should be similarly treated with either white or a lighter shade of the outer colour.

Alternatively, the wall of the trough may be painted chrome yellow—for red tubes—and the outsides with any colour not clashing with the glowing tubes, preferably dark brown. This combination has been chosen by a well-known firm after long experiment to ascertain the colours having the greatest visibility and advertising value.

During the day the bright colours make the sign very attractive, and at night the tubes stand out as flaming lines against an apparently intense black background.

With trough letters two types of electrodes are employed. Before enlarging on this it should be noted that possibly the best position for the tubing on the letters is that in which the centre line of the tubing is on a level with the top of the trough. Thus half of the tubing projects outside and half is inside the trough. This point is important, as it decides the amount of space available for electrodes between the tubing and the background of the letter. With regard to the electrodes, the first method, that of using right-angled electrodes, will depend upon the depth of the trough. If this is 6 inches or thereabouts, as it will be where the height of the letter is more than 3 feet, then this type of electrode is to be preferred. Holes can be drilled in the background directly behind the electrodes, so that access may readily be had for the connection of high tension cables, fitting of pipe glasses and also for maintenance.

Where shallow letters are involved, it is preferable that parallel electrodes be used. The depth required for these is only about 2½ inches, and this is the depth of many trough letters up to 2 feet in height. Where parallel electrodes are called for, bell glasses should, of course, be used. In all cases the high tension cable will have to be brought through the backs of the letters. All wiring will, therefore, be out of sight. Remember to insulate the holes against possible " shorting " between the letters and

the cable. The letters should be bonded together and earthed.

The erection of the letters on the sight follows normal practice, and will be simplified owing to the fact that as the original fixing clips and frames are being used, they will naturally line up quickly into position.

An alternative method of conversion is one in which a thin sheet-metal letter—the precise shape of the converted letter—is soldered into position immediately below the lips of the trough. This has an advantage in that the lampholders and wiring need not be removed nor need the inside of the trough be repainted. With this conversion, if right-angled electrodes are fitted, the lampholders immediately behind the electrodes should be removed, whilst if parallel electrodes are fitted, the removal of any one lampholder will provide a suitable hole for the wiring. Here again the same conditions apply with regard to the colours of the paintwork and also as to the erection of the letters. This conversion is somewhat rough-and-ready, but is cheaper than the first type and has the added advantage of wider appeal.

## § 24. *LOW TENSION WIRING*

The low tension wiring comprises that part of the sign installation which connects the Company's power supply to the transformers, and includes wiring and switch gear, etc., and, if the supply is direct current, the rotary converter. The L.T. (low tension) wiring also embraces the installation of the condensers for power factor correction, and usually the installation of the gear necessary to damp out any interference with radio, etc.

Essentially the L.T. wiring consists of a circuit from the Company's terminals, to the transformer or transformers. Incorporated in the circuit are, starting from the intake, a double-pole iron-clad fuse switch, a double-pole iron-clad switch for general operation of the sign, and a double-pole iron-clad switch for emergency use. This

latter, the "Fireman's switch," must be installed on the outside of the building as already stated, at a height of approximately 8 feet 6 inches from the ground. The switch must be fixed in some position where it can be readily got at by some responsible person, such as a fireman or house electrician, etc., and should be so mounted that the operating lever is UP when the switch is OFF. The reason for this is that a person, such as a fireman or policeman, etc., usually has some weapon whereby he can push, so that by pushing the switch lever he can put out the sign or, what is more important, switch off the current.

From the "sign" side of the emergency switch, the current is taken direct to the transformer, but where more than one transformer is fitted, a distribution board should be installed between the switch and the transformers, the board providing one way for each transformer, so that in the event of a transformer developing a fault, the fuses controlling that particular instrument may be withdrawn without affecting the remainder.

In some cases it will be found that a large number of transformers are required, and that the sign is to be installed at some distance away from the most suitable position for the fire switch. This means that a long length of heavy and therefore expensive cable will be required to run to and from the fire switch, and in addition the size of the switch will be comparatively large to cope with the load of the sign. To simplify matters, and to lessen cost, a contactor switch may be installed, and the fire switch will then consist of a simple 5-amp. switch requiring only a cable large enough to carry this load. The contactor should be installed in some position where the length of run to the sign will be as short as possible.

Where a time switch is required, this is installed between the main switch and the operating switch, although the latter may be dispensed with. The time switch may be either electrically wound or hand-wound, and, if hand-wound, it is usual to install an eight-day clock.

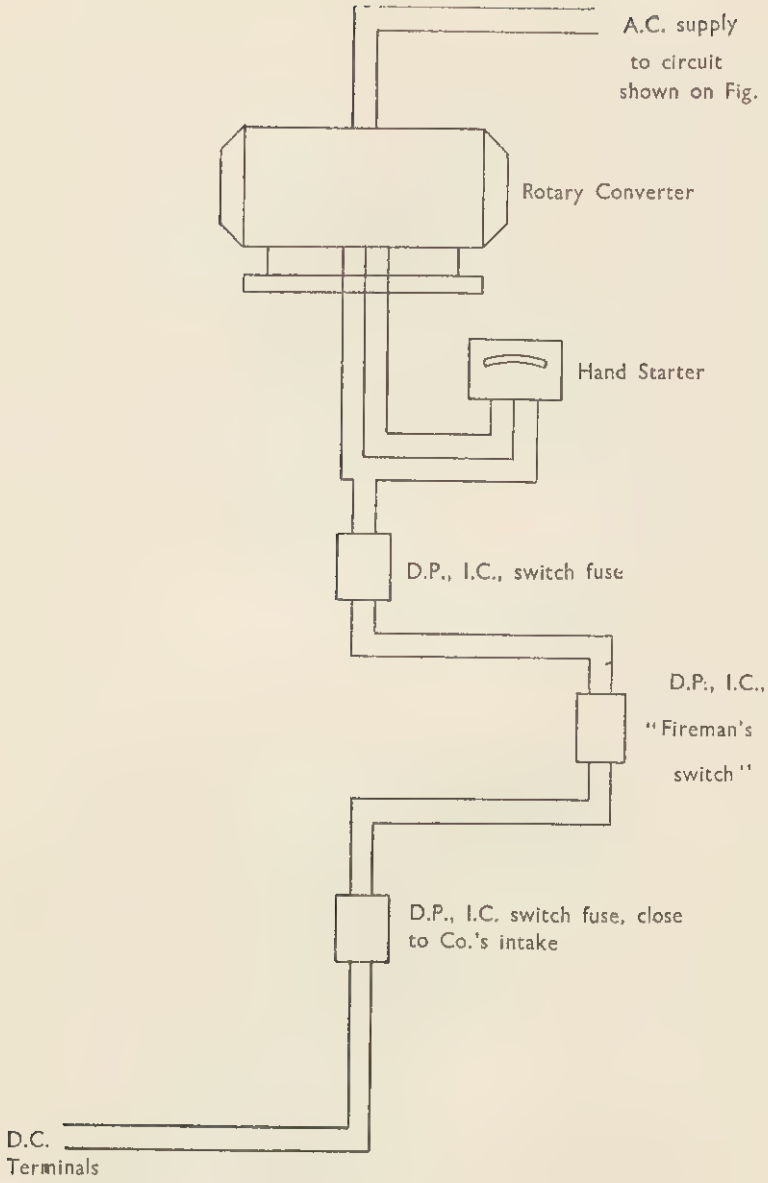



FIG. 10.

Method of wiring a Neon Sign where D.C. is provided.

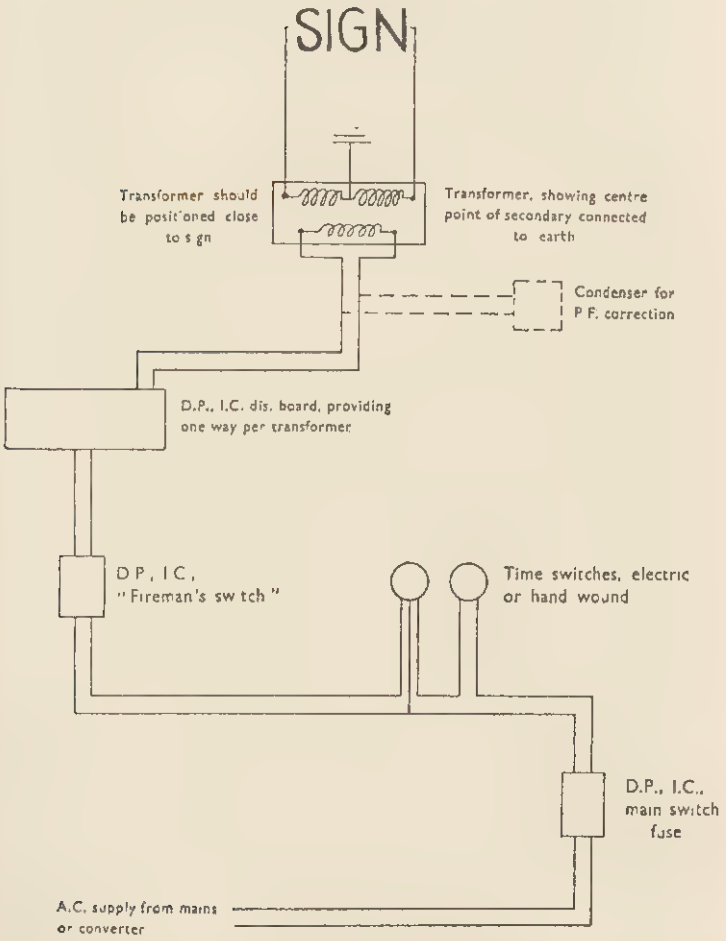

SIGN
Transformer should be positioned close to sign
Transformer, showing centre point of secondary connected to earth
Condenser for P.F. correction
D.P., I.C. dis. board, providing one way per transformer
D.P., I.C., "Fireman's switch"
Time switches, electric or hand wound
D.P., I.C., main switch fuse
A.C. supply from mains or converter

FIG. 11.

Method of wiring a Neon Sign from Alternating Current source, showing necessary switchgear, etc.

Where the current supply is direct, the L.T. wiring becomes more complicated, but the alternating circuit as described above obtains in both cases, with the exception that, with D.C. installations, the fire switch stops the converter.

The simple type of D.C. installation is composed of—starting from the power company's terminals—a double-pole ironclad fuse switch, fire switch as described above, double-pole ironclad fuse switch also as above, converter starter, rotary converter, double-pole ironclad fuse switch, and then through a distribution board to the transformers. If the size of the converter is less than 500 watts, then direct switching may be employed, and the starter dispensed with. If, however, the converter is larger than 500 watts, then a starter is necessary, and if the sign is required to be operated by a time switch, an automatic starter must be installed in place of the hand starter. Here again the time switch may be either electrically wound or hand-wound.

All wiring should conform to the regulations laid down by the Institution of Electrical Engineers, the L.C.C. Fire Brigade, and any Local Authority such as Power Company, etc. The wiring throughout should be run in screwed steel conduit, and a bare copper conductor taken through the conduit should bond the whole of the metal parts together and be connected to an efficient earth, such as a lead water-main.

Figures 10 and 11 show typical circuits for low tension wiring such as are installed for neon sign operation from both D.C. and A.C. Note that the condensers necessary for power factor correction are shown dotted, the reason for this being that power factor correction is not yet generally insisted upon.

## § 25. *POWER FACTOR*

To thoroughly understand the meaning of the term "power factor," a knowledge of alternating currents is

necessary, and the following brief notes outline the main characteristics, at least from our point of view.

If we plot the E.M.F. curve for a simple alternator we will see that in one revolution of the armature the E.M.F. induced will rise from zero to its maximum value during the first quarter of the revolution, and fall again to zero in the second quarter. During the third quarter it will rise again from zero to a maximum, but this time it will be in the opposite direction to that induced during the first two quarters. Finally, in the last quarter it will again drop from a maximum to zero. Thus, the curve for the first

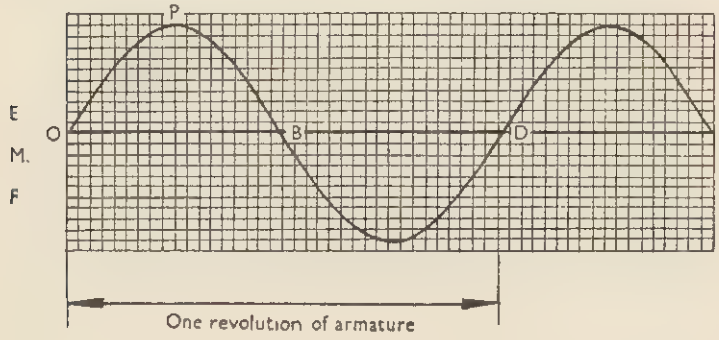



FIG. 12.

E.M.F. curve for simple alternator.

half revolution is above the datum line, and for the second half is below the datum, as shown in the figure. From O to D the E.M.F. passes through one complete cycle, and this is repeated in exactly the same way according to the frequency of the supply. In a 50-cycle supply such as we normally employ, the E.M.F. curve is repeated 50 times per second. This means that the E.M.F. changes its polarity 100 times per second, which is equivalent to saying that the circuit is broken 100 times per second.

If we pass a current from a battery through a loop of wire or other device having inductance—a neon sign transformer possesses inductance—and control the current

by means of a switch, an E.M.F. is set up which opposes the battery current, and tends to delay it reaching its maximum value. When the circuit is broken, *i.e.* the battery switch is opened, the induced current tends to maintain the battery current, and hence to retard its falling. We can thus sum up the effect of inductance by saying that it retards the building up of the current when the circuit is completed, and retards its falling off when the circuit is opened.

From the above paragraph dealing with alternating current curves, we have seen that with a 50-cycle supply, the current rises and falls 100 times per second. This is equivalent to the switching arrangement discussed in the last paragraph, and when we connect a source of alternating E.M.F. to a neon sign transformer, a similar set of conditions obtains. The voltage is continually rising and falling, and the effect of the inductance of the transformer is to retard the building up of the current as the E.M.F. is increased, and again to retard its falling when the E.M.F. is decreased. Consider this statement in conjunction with the graph above. As the E.M.F. increases from O to P there is a tendency to force current in an opposing direction, with the result that by the time the E.M.F. has reached P the current has attained only a fraction of its full value. Similarly, as the E.M.F. drops to B, the current is assisted by the inductance and is sustained, so that it is delayed in falling to zero. Fig. 13 shows the E.M.F. and current curves, and it will be seen that, although they are not superimposed, they are similar. In this case the current is said to *lag*, and the extent by which it lags is measured in degrees. The distance from O to D is equivalent to 360 degrees, and by measurement it will be found that in our illustration there is a 45-degree lag in the circuit.

The E.M.F. and current are then said to be "out of phase," and the extent of the phase difference may theoretically be as much as 90 degrees. In a circuit which had inductance and no resistance, the angle of lag would be

90 degrees, but it is not possible to produce a circuit having no resistance. In a circuit having resistance and no inductance, such as a circuit feeding a number of lamps, the E.M.F. and current are exactly in phase, *i.e.* there is neither lag nor lead. In a circuit such as employed for neon signs, where there is both resistance and inductance, the angle of lag may be anything between 0 and 90 degrees.

At this stage it is necessary to consider what is known as the virtual E.M.F. of an alternating current circuit. From the graphs we see that the voltage is continually varying, and there is no indication of a virtual value.

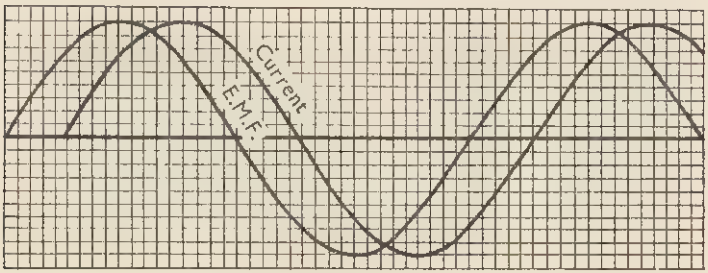



FIG. 13.

Diagram showing lag of current behind E.M.F.

This is found as follows. Take the value of the E.M.F. at a large number of points on the curve, square these values, add them together, and then divide the sum by the number of points taken, thus obtaining an average value of the squares. Now find the square root of this value, and take this as the value of the alternating E.M.F. It is known as the " R.M.S." value, and is the same as the figure which would be recorded on a hot-wire voltmeter. The virtual current in an A.C. circuit is measured in a similar manner.

To measure the power in an alternating current circuit, we must approach the problem in a manner different to that for a direct current circuit, because the voltage and current are continually varying in the former. By taking

instantaneous values of voltage and current at a number of points, we can find an average value of the power, and when the current and voltage are exactly in phase the power can be found from direct current formulæ. When, however, we are dealing with a neon sign load where there is a difference in phase, the product of volts and amperes will not give the true power, but a result known as the Apparent Power, or Volts-Amperes (V.A.). If we know the value of the angle of lag we can calculate the true power in the circuit, but where this value is not known, then it is necessary to connect a wattmeter in the circuit so that we can read the power directly.

We then find ourselves with two readings : one, the apparent power in Volts-Amperes, and the other the true power, in Watts. The circuit then has a Power Factor which is found from :

$$\text{Power Factor} \quad \frac{\text{True Power}}{\text{Apparent Power}} = \frac{\text{Watts}}{\text{Volts-Amperes}}.$$

## § 26. *POWER FACTOR CORRECTION*

The question of power factor correction is important chiefly from the point of view of the supply companies, for reasons which will be obvious from the above paragraphs. For instance, a transformer with a power factor of ·45, a not uncommon figure for an uncorrected installation, uses 45 per cent. of the total current in producing useful energy, and the other 55 per cent. merely circulates in the generator circuit. The power company is paid only for the 45 per cent. actually consumed by the sign, but in order that the sign can consume this 45 per cent., 100 per cent. must be provided in the circuit.

The power companies have two ways of dealing with their problem, and these are to provide a two-part tariff, or to demand that the power factor be corrected to ·8 or 80 per cent. The two-part tariff system means that the consumer pays in accordance with a scale which is com-

posed of two parts, namely, the apparent power and the true power. Thus, if he uses a low-power factor sign he has to pay more for running it.

Apart from the two-part tariff system, the consumer may be hit in a different way if he uses low-power factor equipment. If his supply is D.C., then he must first convert to A.C. before feeding his transformers, in which case he assumes the part of the power company. If his transformer—assume he has only one—actually consumes 450 watts and it has a power factor of ·45, then he must generate 1 K.V.A., which costs him more for running, and also requires a bigger initial outlay. With a big installation requiring, say, thirty transformers and a rotary converter, it will be found cheaper to correct the power factor to ·8.

Power factor correction of neon signs is effected by connecting one or more condensers in the primary circuit, the action of the condenser being as follows :

If a battery be connected in series with a switch and condenser, before the switch is closed the value of the battery will be, say, A volts, whilst that of the condenser will be zero. When the switch is closed, the condenser will be charged and the voltage across its plates will be equal to A. At the instant the switch is closed the voltage across the condenser is zero, and the current is a maximum, but as the condenser becomes charged the current drops, until when there is no potential difference—or P.D.—between the battery and condenser, the current becomes zero. If we again substitute our alternating current supply for the battery and switch, we see that a similar train of events occurs, and that the current leads the voltage. That is, the effect of a capacity in the circuit is to cause the current to lead, the extent to which it may do so depending upon the resistance of the circuit, with a theoretical maximum of 90 degrees. In a circuit having only capacity and no resistance, there would be a 90-degree lead, but, as we have already seen, it is not possible to completely eliminate resistance.

We know that a purely inductive circuit will have a lag of 90 degrees, that a circuit having only resistance will have no phase difference, and that a circuit having only capacity will have a lead of 90 degrees. Now in a circuit having all three factors, there are two in definite opposition, namely, inductance and capacity, and it is quite possible to have a circuit in which the effect of inductance is just balanced by that of capacity. This, then, is the method adopted to correct the power factor of neon signs, or, in other words, to bring the current and voltage into phase. The value of the condenser necessary is usually found by actual experiment rather than by calculation, for reasons which will be obvious from the following.

The foregoing remarks are based on the assumption that the voltage and current curves are of truly sine form, or, in other words, are truly sinusoidal, that is, the voltage and current at any given time obey the established formula. It is possible to prove that this is the case only by taking oscillograms, and by this method it has been shown that the voltage wave-form is appreciably distorted from the sinusoidal form, and that it is very nearly in phase with the current wave-form. Thus, the variation from unity of the power factor is due not only to a phase displacement, and the simple power factor relationship no longer holds true. This relationship obtains only where the wave-form is sinusoidal, and where it is distorted the power factor must depend upon the distorted wave-form. It is evident that such a distorted wave-form contains harmonics of a high magnitude, in which case the power factor depends upon the relative *magnitude* of the harmonics, and not so much upon the relative *phase* of the harmonics.

The use of condensers in a circuit having a greatly distorted voltage wave-form is quite likely to give rise to surge voltages of a magnitude greater than that for which the insulation is designed, and for this reason the installation of power factor correction condensers must be carefully checked.

## § 27. *CONTROL OF NEON SIGNS BY TIME SWITCH*

The Neon sign, a comparatively simple electrical installation, can readily be controlled by a time switch. Time switches may be of the clock-wound or electrically wound type, and can be set to switch the sign on and off at any predetermined time. When the installation is run off D.C. and the size of the motor or rotary converter is greater than ·5 K.V.A., then it is necessary to install in conjunction with the time switch an automatic starter for the rotary converter. This replaces the hand starter, and consists of a clapper switch which allows the current to pass to the converter through varying resistances. As the machine speeds up, the resistances are cut out one at a time until the machine is running at full speed. When the time switch cuts off the current, the clappers drop back until the time switch switches the current on again, when they go in one, two, three, etc., depending on their number.

## § 28. *FLASHERS*

The use of flashers in conjunction with neon signs is not nearly so extensive as with bulb signs, and for a very simple reason.

On designing a layout for a flashing sign, the complete sign is first split up into a number of groups or " circuits," each group representing a separate unit for flashing. For example, the sign may consist of twelve words, and the scheme requires that each of these words flashes on one after the other. Therefore we have twelve groups or circuits, and we know that a twelve-way flasher will be required. Now, if the sign were a bulb sign, each word would be composed of a number of bulbs, and all of these bulbs would be connected together to one common pair of cables, and this pair of cables led to its appropriate place on the flasher terminal board. All that is necessary, then, is for the flasher to make or break that particular circuit,

and one set of bulbs or one word flashes on or off. With a neon sign, however, the case is somewhat different. This type of sign requires, as we have seen, high tension gear in addition to the tubes—which we may consider as being equal to the bulbs in a bulb sign—and cables, so that not only must the tubes flash, but the transformer must be switched on and off. This appears straightforward enough, and as far as that goes it is extremely simple.

The trouble appears, however, when we realise that one transformer is operating perhaps three words, and the scheme calls for a flasher to flash each word separately. Obviously we cannot switch off one small part of the current so that the required word goes out, and it is not practicable to switch the high tension side. Whatever flashing is done must be done on the low tension side of the circuit, that is, the side on which the distribution board is situated, and we are then faced with the problem of making each word—if it is required that each word shall flash separately—or each letter, as the case may be, a separate unit provided with its own low tension circuit and transformer.

If the sign is a large one, and each circuit would normally require more than one transformer, then the only additional expense involved is that of the flasher and a little for extra wiring. Flashing window signs are, however, almost ruled out unless it is desired to merely flash on and off, or unless expense is no object.

As we have said, the flashing or animation of a large sign becomes a simple matter, but generally the use of flashing neon signs is limited to those of the national advertisers who can afford whatever extra expense is involved, and willingly do so to obtain a sign that is " different."

A brilliant example of a flashing neon sign was, until recently, to be seen in Piccadilly Circus, advertising a popular raincoat. In this scheme the flashing or animated part took the form of falling rain, and the rain was composed of a series of 12-inch lengths of tubing so connected together that it gave the appearance of a regular downpour of rain.

There were about forty sloping lines of tubing, and each of these lines was about 12 feet long and composed of twelve 12-inch lengths of tubing which represented the raindrops. These " drops " were staggered in relation to their immediate neighbours, and were connected together in twelve circuits of forty drops, so that if one circuit was lit up and remained so, it would appear in the form of a zigzag line composed of forty 12-inch lengths of tubing. Each circuit was connected to the flasher in such a manner that when the sign was working, the light started from the top and worked downwards. When about the third or fourth set was reached, the action started again from the top, and so we saw what appeared to be a continuous fall of glistening drops.

Neon sign electrodes are by virtue of their peculiar properties particularly suited to flasher operation, and some very effectively flashed signs have been built and are running satisfactorily.

An American firm has introduced a high tension flasher known as an " animator," with particular reference to the animation of novelty window signs. It can flash three or more circuits on one transformer, and does this by means of spark gaps. Whether it would be permitted in England is somewhat doubtful, but it certainly is responsible for the development of some very good novelty signs. A simple type of flasher recently introduced from America is of the mechanical type and is of great value for small novelty signs such as pointing arrows, expanding circles, etc. The flasher is inexpensive to buy, consumes very little current, and owing to its slow speed is almost trouble-free. It has, however, only a limited field of application, and owing to the fact that it cannot deal with heavy currents is unsuitable for large flashing installations.

## § 29. *PERIODICAL CLEANING OF THE TUBES*

In order that a neon sign may continue to work at its maximum intensity of illumination it is necessary to keep

the tubes in a clean condition. This is particularly important in industrial areas where neon signs are most numerous and where the continually sooty atmosphere causes the tubes to become coated in a very short time. The longer a neon sign is kept alight the dirtier it becomes, because the static electrical attraction of the tubes causes minute particles of dust and soot floating in the atmosphere to be drawn to them, where they are cemented if moisture is present, as it invariably is.

The static action of a neon tube is analogous to that of a piece of amber, which when rubbed on a silk or woollen surface assumes a static electrical charge and can be made to employ this energy by attracting small pieces of tissue paper.

A maximum period between tube-washing operations is two months, with a qualification that where the tubes are positioned near eye-level, washing should take place either fortnightly or monthly. These figures do not, of course, apply to box signs where the tubing is protected by a glass panel, when it is necessary only to clean the panel.

The cleaning of neon tubes demands that extreme care be exercised. The following two points, although they may seem a trifle redundant, are of importance and cannot be too greatly stressed.

First, switch off the sign and remove the fuses or the key of the locking switch before commencing to clean. Then knowing that no harm can come to you during the operation from some unthinking person attempting to switch on, carry on with the job.

Secondly, do not lean the ladder against the tubes. It is surprising the number of tubes which are returned for repair because the cleaner leaned his ladder against them.

For cleaning the tubes use a wash leather, not a cloth. Cloth has the distressing trait of possessing a large number of ragged ends which seem to wrap themselves automatically around the tubes and defy all efforts to remove them without first breaking the glass.

A choice of cleaning fluids is available. The most

common is of course cold water, but this is not very efficient. Warm water is better, although here again the grease which is removed from the tube by the leather is not dissolved by the water, with the result that although the tube may be clean it will be left with a thin sticky film of grease, and it will be dirty again within a very short space of time.

The addition of a little ammonia to the water results in a big improvement, whilst the addition of vinegar in lieu of ammonia also has the effect of removing the grease from the wash leather and so enables a clean, dry tube to be achieved.

Vinegar and ammonia have the advantage that they can be readily carried about, with perhaps a slight extra advantage on the side of vinegar, which can be bought very cheaply at any local general stores. Special cleaning preparations are marketed, but these have varying degrees of success. When performing the actual cleaning operations do not press too hard against the tubes. Where possible, support the back of the tube with one hand whilst cleaning with the other, so that no strain is imposed. Where the tubes are recessed and supporting is impossible, extra special care is advised.

The cleaning of neon tubes, although important, is not a difficult matter, and if one or perhaps two men are given this as a more or less permanent job, it becomes a simple routine matter and breakages will be few and far between.

## § 30. *ACCESS FOR MAINTENANCE*

Maintenance of neon signs is necessary if they are to function satisfactorily and continuously for any length of time. In this respect neon signs are not unique, as all apparatus—and a neon sign is a piece of apparatus—requires a certain amount of attention to enable it to operate efficiently. It is a fact, however, that the maintenance of neon signs is not so heavy as that of other types of electric signs—notably those using bulbs—and if due care and

attention are provided both before and after the installation of the sign, and if also a definite programme of trouble-searching is carried out, neon signs can be maintained with a minimum of trouble and expense.

So far as the necessity for maintenance is concerned, the sign may be split into three groups, these being, in order of frequency of trouble, the Wiring, the Glass, and the Transformers. Failure in either one of these groups means that the sign will not be in operation, and the cause of the failure must therefore be attended to as quickly as possible. It is here that the necessity for a carefully planned installation becomes apparent, and where there is a penalty clause in the contract immediate attention to trouble is of vital importance.

The sign should not be fixed in such a position that access may be had only at the expense of erecting cradles. If, however, erection under such circumstances is necessary, provision for the slinging of either cradles or a bos'n's chair should be arranged during the erection of the sign. This increases somewhat the cost of the installation, but it is the duty of the sign manufacturer to quote for the complete job, and if he undertakes the maintenance of the sign, then the provision of the required equipment is part of his contract.

With some large signs it is possible to fix a platform around the sign so that a man may have access to all parts without the use of any equipment other than his hands and feet. The platform method is advised wherever possible, as it is comparatively inexpensive if built in conjunction with the sign, and is, in addition, very steady and rigid, allowing the erector or maintenance man to work without danger of breaking the tubes through his footing being insecure. The platform may be arranged adjacent to a window or roof for easy access, or, if such arrangement is not possible, an iron ladder between the platform and window or roof can easily be fixed. Usually a ladder of this type is fixed parallel to the face of the building, and can, if necessary, extend up to and over the parapet wall

or pediment, as conditions demand. The transformers can be accommodated on the rails behind the sign, in which case they are immediately to hand, and the length of high tension cable is reduced.

The transformers should be of the waterproof type, and the cable ports so protected by spouts that the ingress of water, even under storm conditions, is prevented.

Suitable ventilation must be provided if the transformers are boxed in, so that condensation of the atmosphere will not impair their insulation. The high tension cable should be fixed in such a manner that it can readily be got at, but this fixing must be carried out so that it is not necessary to move the cable unless some big replacement is about to take place. Tests carried out to find exactly the causes underlying the failure of cables have shown that under normal conditions of installation the cable will be perfectly trouble-free for years, provided it is not moved. Where the cable is installed under such conditions that it is necessary to move it every time an inspection of the sign is carried out, it has been found that its life is considerably shortened. A parallel may be struck here in the case of the ordinary electric wiring for houses. Cases have occurred where wiring, installed so long as fifteen years ago, has given perfect and reliable service, but after some alteration necessitating the moving of the wire, the insulation has fallen apart and complete renewal of the wiring necessitated.

Similar conditions exist with neon sign wiring, and provided that the cables are fixed rigidly in position and are allowed to remain in where set, very little trouble will ensue. It is, however, necessary to provide that renewal can be undertaken when required, so that the cable must not be too securely anchored.

The collection of moisture in and around the electrode housings is a source of trouble, and the arrangement of the housings, whether of the usual bell-glass type or of the more modern and efficient porcelain type, must be such that they can readily be got at for inspection. The same

applies to the series connections between the tubes. These must be accessible for inspection, and should not be so securely attached that they cannot be tested when required.

With small signs the question of maintenance is rather apt to be overlooked, partly due to the fact that the question of expense is usually of paramount importance and the deciding factor for or against the sign, and partly because the sign manufacturer thinks that the job is so small that if anything goes wrong he can take the whole sign down single-handed. This is a mistake, and it will be found that with small signs fixed near to the footpath, greater attention must be paid to the appearance of that sign than to a sign fixed, say, 60 feet above ground. This means that as much as possible of the " works " should be hidden, and it is not until some trouble occurs that the manufacturer realises how successfully the said " works " *have* been hidden. So much so, that in some instances the whole facia has to be dismantled to get at a faulty connection or other defect.

With a high sign, all sorts of odds and ends may be left hanging without the public down below noticing anything other than what they are intended to see, namely, the message broadcast. The desire to hide as much as possible is somewhat of a craze with certain people, and the signman in this position must see that he has free access to his hidden treasures from perhaps the back of the facia, before he locks them up.

An important point which should receive attention is in connection with the provision, at a suitable height for ready access, of a fuse-board controlling the transformers. In some cases a serious breakdown may be avoided if immediate attention is given to withdrawing the fuses controlling the defective section, be this glass, transformer or high tension wiring. It is the general rule to feed each transformer from a separate circuit, each circuit being provided with a two-pole fuse. The fuses are built in together into what is known as a " Distribution Board," so that in

the event of any one or more circuits failing, the fuses of those circuits may be withdrawn without interfering with the working of the rest of the sign. To facilitate the withdrawal of the correct fuses, the space provided inside the cover of the distribution board should be clearly marked with the particular sections of tubing controlled by the various fuses. In this way, and provided that the necessary instructions regarding the withdrawal of the fuses are left with the sign owner or other responsible person, he can pull the correct fuses as soon as he sees that part of the sign is not functioning properly.

## § 31. *SOME COMMON FAULTS AND THEIR LOCATION*

The following paragraphs show the more or less common faults of neon signs, how it is possible to locate them, and to what cause the fault is due.

1. *The Whole of the Sign is Out or "Dead."*—Check over the fuses, and if they are all in order, test the primary circuit with a lamp at each point until the fault is located. The trouble here will be a bad or loose connection, or a blown fuse.

2. *The Whole Sign is Flickering.*—This may be due to either a faulty connection on the primary side, or a drop in primary voltage due, perhaps, to a heavy load being imposed on the mains. Check over all connections, and test voltage with a voltmeter.

3. *All the Tubes on one Transformer are "Dead."*—Inspect the fuses, and check over for faulty connections in the particular circuit. Test the transformer by disconnecting the high tension leads and installing a short piece of stiff wire on each high tension terminal with their ends separated to form a gap approximately $\frac{1}{4}$ inch wide. Replace the fuses and switch on. If the current does not jump the gap between the wires, the transformer may be assumed to be defective and should be replaced. A further check on the transformer may be made by insert-

ing a new transformer into the circuit. Test for dead tubes in the circuit, by shorting out each tube in turn. This is effected by inserting a piece of wire in place of each section of tubing, and switching on. Repeat the process with all sections, taking care to switch off each time. If a faulty section is found, remove the glass, and leave the shorting wire in position. Never leave the transformer switched on with an open secondary, or it will be severely damaged. Finally, test the transformer and H.T. connections and leads to see that the current is not leaking away to earth.

4. *All the Tubes on one Transformer are Flickering.*—Check for loose connections on both primary and secondary sides. Check for leakage to earth. Test transformer by replacing with another. The spark gap test is not very effective in this case, and in fact cannot ever be regarded as infallible proof that a transformer is O.K. merely because it will cause a spark to jump a gap, unless the gap is very carefully calibrated. Test tubes with shorting wire for faulty section. If none of these tests indicate where the fault lies, it may be that the tubes have had their normal period of life and have " hardened." This means that some of the gas has been occluded by " sputtering " of the electrodes, with the result that there is a greater degree of vacuum in the tubes and their resistance is increased. To overcome this increased resistance a larger transformer is necessary, but this will only temporarily alleviate the distress. When such a state obtains, it will usually be found that the whole of the installation is in a similar condition. If this is so, the best treatment is to re-gas the whole of the tubing. It may be, however, that only one section has " hardened," due possibly to the wrong pressure of gas being filled into the tube during manufacture ; but even if this is the case it is rather difficult to trace, and to find it requires greater skill than the location of a cracked section.

For expansion of the factors affecting the life of neon tubes, see the paragraph headed " Life of Tubes."

5. *One Tube is Dead, the other Tubes on that Transformer*

*are Flickering.*—This is an almost certain indication that a section of the tube is faulty. Test the dead tube by inserting a shorting wire across it, when the remainder of the tubes will probably glow brightly. Remove the faulty section and leave the shorting wire in position.

6. *Some Tubes on a Transformer burning brightly, while the others are not Burning.*—Test for an "earth" on the high tension side at the electrode connections to the dead tube or tubes.

7. *Fuses keep Blowing.*—This indicates that there is a short circuit to earth, or a dead short across the primary. If it is the main fuse that blows, work backwards from the sign by disconnecting—one at a time—each transformer at the fuse box, and then checking over the junction points. If the cutting out of one transformer indicates where the trouble is, carefully check over all the connections to that transformer.

Finally, when working on a neon sign, either in erection or maintenance, remember that you are working on high voltage apparatus. The prime rule is: WITHDRAW ALL FUSES BEFORE WORKING ON OR IN CONNECTION WITH THE NEON SIGN, OR REMOVE THE KEY OF THE LOCKING SWITCH.

An interesting point with regard to the shorting out of sections to isolate that section which is faulty is that, whereas a broken or badly cracked tube will not glow under any conditions, a good tube will glow even when connected to a transformer with an open section circuit. This glow is due to inductance, and sometimes where a burnt-out transformer is located there may be a glow in some of the tubes connected in that transformer circuit, but caused by an "external" inductance.

When shorting out sections of tubing on a flickering sign, the faulty section will generally be off-colour. This is due to air entering the tube and mixing with the gas, and whilst such a tube will cause a flicker due to the higher voltage necessary to "strike" the "weakened" mixture, the colour is sometimes not very different from that of the

surrounding tubes. This is particularly noticeable in the case of helium-filled tubes, which glow a pinkish-white. If air enters such a tube, the resulting colour when the tube is alight is little removed from that of the correct tube, and will often confuse the maintenance man. It will be obvious to him, however, when he *does* locate the faulty section, as there will be a perceptable brightening of the remaining tubes. The shorting out of one good tube amongst a number of good tubes and one bad one will make comparatively little difference, whereas if the bad one be shorted out the difference will at once be apparent.

If a faulty section is located, and it is decided to short this section out with a piece of wire so that the remainder of the sign may be left burning, see that the shorting wire does not cause trouble by earthing. The best method is to enclose a piece of bare wire in a thin glass tube, this tube stretching from terminal to terminal of the removed section, and supported if possible from all earthed parts of the sign such as framework, transformer casings, etc.

## § 32. *ELIMINATION OF RADIO INTERFERENCE*

Cases where interference with a radio set coincides with the installation of a neon sign are more or less common, and although it is not always that the sign only is at fault, this certainly has something to do with it.

The interference of broadcast reception by neon signs is not by any means a recent phenomenon, but it is becoming increasingly important by virtue of the fact that a larger number of people are now using mains receivers, and, in addition, a larger number of people are listening-in.

Most interference is high frequency in character, and, as is well known, is due to changes of current in the circuit, so that the ways in which a neon sign can be responsible are easily seen. The nature of the interference depends upon one or two causes. " Broadcasting " interference is caused through the wiring acting as a transmitting aerial and broadcasting radiation, or, in other words, radiating

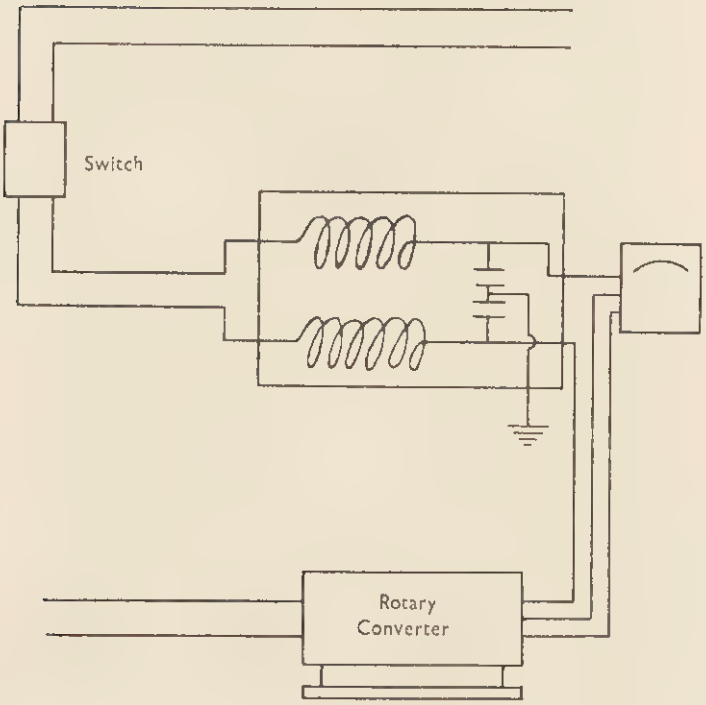



FIG. 14.

Circuit designed to eliminate interference with radio. The condensers have a value of 2 mfd. or over, whilst the chokes which have an equal number of turns each consist of cable hank or bunch wound to a diameter of 8 inches. The size of the cable is decided by the current in the circuit.

waves which are picked up by the aerial of the radio set. The other type of interference is known as "feedback" interference, and is caused through the generation of high frequency impulses in the secondary winding of the transformer. These impulses or high frequency currents are fed back through the primary circuit and so into the supply mains, where they are picked up by the sets drawing their supply from the same mains.

Broadcasting interference may be eliminated if proper care is paid to the earthing of all metal parts, and, if possible, the transformers and other gear should be installed in an earthed metal box. This latter remedy is not, however, generally necessary, as little trouble is experienced with low frequency installations such as are used to-day, and any interference which does arise can be eliminated quite simply.

An effective method of elimination consists in connecting a small inductance in series with the tubing at some points in the high tension system, and a further method is to paint a strip of metallic paint along the back of each tube and connect this to earth.

Feedback interference may be eliminated by connecting two $\frac{1}{2}$-mfd. condensers in parallel with the primary of the transformer. The two condensers should first be connected together in series, and the centre point connected to earth.

Fig. 14 shows a circuit approved by the Post Office for the elimination of interference by neon signs, and this has proved very successful. An alternative consists in connecting a small choke of about 30 henrys with each transformer. This is inserted between earth and the middle point of the tubing circuit.

## § 33. *METHODS OF MERCHANDISING*

From a general point of view the first and best method of merchandising neon signs is to sell them outright for cash, but as neon signs of any size involve the expenditure

of an appreciable sum of money, the potential buyer often expresses the wish to acquire his sign on the hire-purchase or hire-maintenance system.

A buyer to-day is generally unwilling or unable to pay a large sum in cash for a sign which is to be used for a period of years. He considers, perhaps rightly, that such a sum should not come out of one particular year's publicity or advertising expenditure, but prefers to spread his payment over a period of, say, three or five years. This is all for the good of the trade, as, whilst his order would possibly be a small one were he compelled to pay prompt cash, he feels he can "let himself go" a bit if payment is spread over a protracted period.

There are alternative methods of merchandising neon signs :

(1) Outright cash sale.

(2) Hire purchase by 12, 24, 36, or any agreed number of equal monthly payments, in which the first monthly payment may be regarded as a deposit and should accompany the order. It is customary that the deposit, instead of being only the first monthly payment, be any figure from 10 to 50 per cent. of the cash price. Naturally, interest charges are added for the accommodation, varying according to the period of the spread-over, and dependent also upon whether the manufacturer finances his own transactions or conducts them through a finance house. Through the latter, the minimum charge is in the neighbourhood of 4 guineas, so that if the payments of a small sign of, say, £25 has to be spread over a period, the accommodation will cost as much as for a £75 sign, and must be taken into consideration when preparing the agreement.

Payments may be effected by banker's draft, post-dated cheques, or by bills. If possible, endeavour to obtain some form of collateral security for the balance outstanding, as, in the event of payment being in arrears, or default, you then have a certain course of action. The sign or display has practically no recovery value, and is

useless to any other party, as it has been made to order and to a particular design, embodying special wording, layout, size, etc. This individuality of the neon sign, particularly with hire purchase, demands that the manufacturer protects himself as completely as possible against default by the purchaser. Apart from the fact that the latter may be willing to pay his instalments when due, but has no money with which to do so, his only reason for defaulting is that the manufacturer does not give adequate service. To give this service, the manufacturer must be sufficiently covered, and must, therefore, impose a charge additional to that for accommodation, for maintenance.

The inclusion of a maintenance charge in a hire purchase transaction is absolutely essential, as, if omitted and the normal guarantee service is relied upon *or has expired*, it will be difficult to persuade the customer that any breakdown will not exonerate him from his liability to maintain regular payments as specified by the agreement.

Maintenance charges vary with the service to be rendered. For instance, for ordinary attention which may be necessary during the period of guarantee—six or twelve months—free service is given or is implied. Yearly maintenance beyond the guarantee period is usually 10 to 15 per cent. of the cash or outright sale price. This maintenance service covers everything, including periodical attention to the whole apparatus, replacement or repair of faulty tubes, and tubes broken through either accident or malice, replacement or repair of transformers, etc., a three-monthly wash-over, overhaul of all wiring, and a repaint once yearly.

The variation in the percentage above is controlled by the size and accessibility of the sign to be maintained ; for example, if the price of the sign is £40 it would be uncommercial to charge only 10 per cent., as the number of attentions would *cost* at least that percentage ; 15 per cent. would be a more reasonable figure, and would cover the necessary service. Should the sign cost, say, £100, then 10 per cent. would suffice, provided that the tubes

and connections were at hand and not unduly inaccessible.

Should maintenance cover attention to border or strip-lighting tubes spread over the entire face of the large building, 15 per cent. would be necessary, with a *contra* allowance for unrequired paintwork.

A simple facia sign stretching over, say, 20 feet can easily embody some 60 feet of tubing, and the maintenance engineer can service this with possibly only two alterations of his ladder position. The cost of the sign may be £50. If £50 be spent on strip-lighting or border tubing, however, 80 feet of tubing will probably be involved and this may be spread over, say, a horizontal run of 40 feet and two vertical drops of 20 feet each. To service this will require a great many alterations of ladder position, and the maintenance engineer will have to cover a much greater area involving the expenditure of more time.

Thus maintenance must be increased by at least 5 per cent. should the installation be operating on Direct Current, as a Rotary Converter will be in service here, with consequent need of attention. As the guarantee on a rotary converter is limited by the manufacturer to twelve months, it is obvious that due allowance must be made for any breakdown in subsequent years.

There must also be a proportionate increase in maintenance charges if every little attention necessitates the erection of a cradle or scaffold for such service. This charge may sometimes reach a figure as high as 40 per cent. per annum. This is, of course, an extreme case, but it can be appreciably reduced only by the erection of a permanent steel ladder or platform, suitably railed off, to give access to the tubes and transformers. The cost of installing this very necessary maintenance plant should be an initial one, and invoiced to the customer separately at the outset, and not included in the annual maintenance charges. For facilities for maintenance, see the Section on "Access for Maintenance."

Another method of neon sign merchandising is :

(3) *Hire-Maintenance System.*—This, as the title implies, is a hire-with-maintenance service, the sign remaining the property of the manufacturer always.

There is much to be said in favour of this method. It relieves the customer of all worry, as, in consideration of a fixed monthly or quarterly payment for a period of three or five years, he is provided with a sign burning brilliantly day and night, always clean, and never or rarely out of order. Should the sign be inoperative for a period of from forty-eight to ninety-six hours—according to the agreement—a penalty is exacted from the manufacturer by the hirer.

The monthly charge—or rent—has a further advantage in opposition to outright sale or hire-purchase, as it can be debited to rent account as a fixed or necessary expense, and consequently not subject to Income Tax—a consideration in these difficult times. It will be appreciated that in all matters appertaining to hire—whether of signs or sewing machines—the whole of the nett cash price should be covered by the hiring agreement if the hire period is of such a length that the goods will be useless to any other party after the term has expired. As neon signs are practically useless to any one other than the original user, it will be realised why neon sign-hiring agreements cover fully the cash selling price of the sign.

The method usually adopted in calculating or assessing the monthly charge or rent is as follows : To the cash price of the sign, add three years' full and complete maintenance charges and three years' interest. The biggest drawback is going to be the maintenance of the sign. Remember, there are three years' constant attention to allow for, and the charges must cover the perpetual visits involved. Possible breakages, malicious or otherwise, insurance against fire, third-party risks, etc., in fact every possible contingency must be taken into consideration, including washing the tubes fortnightly or monthly if requested, replacement of transformers, cables, etc.

This formidable list of "allowances" and "provisions" and "possibilities" is enough to deter any one from ever entering into a hire-maintenance agreement - from the selling side, of course! But the picture is not so bad as it is painted. The dark side only has as yet been shown.

To return to figures. Allow 10 per cent. for the first year and 15 per cent. for each of the subsequent year's maintenance, if the current supply is A.C. (The customer is entitled to a limited free service for the first year, which, however, does not include washing or repainting—hence the 10 per cent.) We have now a total of 40 per cent.—three years' maintenance—to be added to the cash price, plus a further 20 per cent. as three years' interest charges, and approximately 10 per cent. as a general charge to cover risk, etc., making about 70 per cent. in all. If the outright sale price is, for example, £100, then the total hire-maintenance charges would be £170 spread over three years, or approximately £4, 14s. 6d. per month for thirty-six months. Should the hiring term be of, say, three years' duration, and after this period has expired the hirer desires an extension of three years, then it is usual to charge half the former monthly rental. This will cover the cost of maintenance and possible replacement of transformers and remaking of tubing which after three or more years' continual operation may be considered to have served a useful life.

An advance payment of a sum equal to the first quarter's rent is usually demanded of the customer, and this sum, together with references and the subsequent signing of the agreement, ensures installation. The taking up of references should be exhaustive, and leave no reasonable doubt in the mind of the manufacturer as to the ability of the hirer to meet his obligations.

We have set out above the selling methods usually employed by neon sign manufacturers. By selling is meant the actual contract entered into by the customer with the manufacturer, not the procedure adopted by the

salesman for the creation of sales. This procedure deserves a treatise to itself, but it is not the purpose of this book to discuss ways and means of neon sign selling.

## § 34. *ON TAKING PARTICULARS*

Generally, when an inquiry for a sign is received, the information given is insufficient to enable an estimate to be prepared. It therefore becomes necessary to obtain further particulars, and in this connection the following few points should be observed :

Sometimes the client may provide a complete specification and drawing, in which case it is necessary merely to check over any points which may not be clear, and to see that the client's details indicate all that is of interest to the sign contractor. Where, however, the client has only a hazy notion as to what he wants, and is relying on the contractor to provide a scheme, the first job is to go with him to the site and find out exactly how far his ideas are fixed, and to what extent he requires assistance. Possibly the most important question is in connection with the amount he is prepared to spend. He will probably indicate this to within a reasonable limit, and the next thing to do is to find out what he requires as the nucleus of the installation. For instance, he may suggest that he wants his name to stand out boldly, say, in about 18-inch letters, and, as a supplement, some form of outlining. If he is prepared to spend only about £30 to £40 on the job, then he can have either the facia sign alone or the outlining, according to which, in his estimation, is the most important. A client's first indication of the limit to which he is prepared to go should not always be taken as final, and the process of increasing this limit comes within the sphere of the salesman !

A rough sketch of the building should be made—more or less to scale—and those dimensions which will be important in quoting for the sign, and also in the subsequent erecting, should be taken. If the sign is to be of the

facia type, then the height of the facia, its length, and the height above the ground should be measured. In all cases the height of the proposed installation is necessary in order to find out if cradles will be required. With regard to the erection of the sign, there may be some local regulation which prohibits the use of ladders during normal hours, in which case cradles will probably be necessary. Again, the client may require that the sign be erected only within certain hours, and this will invariably affect the estimate.

If a projecting sign is required, the width of the footpath must be taken into account. In the case of a wall or facia sign to be fitted flush with the premises, but which also projects over the footpath, the local authorities' regulations must be considered in so far as they will affect the size of the sign.

Make a note of the material to which the proposed sign is to be fitted. It may be of glass, stone, bronze, brick, marble, etc. This is important, as the time required for boring the holes necessary for the mounting of the letters and rails, etc., may be very considerable in the case of a hard material and where there will be a large number of such holes. Also there is a big risk attendant on drilling glass facias *in situ*, and, if possible, the rails should be fixed to the facia framework. Find out if this is suitable for such treatment.

A rough approximation of the footage of the sign may be made, from which an estimate of the number of transformers will easily follow. Look around for a place or places where the transformers may be lodged, as upon this factor depends the amount of high tension cable which will be required. In taking particulars prior to quoting for the low tension wiring, the first thing to ascertain is the nature of the supply, *i.e.* is it alternating or direct current. If it is alternating current all is well, but if only direct current is available, then a rotary converter will be necessary, and, if it is only a small sign, then the fact that D.C. is present may squash the whole project.

Measure the run between the supply meter and the sign, taking into account the number of walls through which the cable will pass, and also the number of corners around which it must turn. When carrying out this measurement, remember that a fire switch must be fitted at a height of about 8 feet 6 inches from the ground, and in a convenient position for operation in the event of a fire. If a number of transformers will be required, a distribution board is necessary, and a position for this should be chosen so that it will be close to the transformers.

With a D.C. supply, the position for the rotary converter must be arranged with the client, and particulars taken of any foundation which may be necessary.

Elicit if the client requires a time switch, and remember that if D.C. and the converter will be larger than ·5 K.V.A., an automatic starter will be wanted, as straight-through switching would damage the machine. Find if power factor correction is necessary.

## § 35. *A METHOD OF CALCULATING TUBING FOOTAGE*

Usually a first consideration when planning a neon sign is the amount of tubing it will involve. This naturally has an important bearing on the number of transformers which will be required, and the method of calculating the footage generally adopted by neon sign manufacturers is given below. This method is somewhat rough-and-ready, but is quick and fairly accurate. It is not always convenient to measure the job carefully—at least in the early stages of its development, although careful measuring is necessary when the full-size layouts are being prepared.

To arrive at the footage required for ordinary BLOCK type letters, multiply the overall height of the letters by THREE, irrespective of whether they are M's, L's, I's, T's or S's. This calculation applies to single-outline letters only, and a definition of the term " Ordinary block type " is

perhaps desirable. An ordinary block type letter is generally accepted to refer to a letter the width of which is approximately two-thirds of its height. Thus a 12-inch block letter would have a width of about 8 inches. There are, of course, exceptions to this rule, as, for instance, in the case of the letters " I " and " W." The ruling applies, however, as an average value. For normal sign work, the ordinary block type letters look rather thin, for the reason that although the background letter is of correct proportion, the neon tube or centre-line of the latter does not follow out the same ratio of width to height.

Usually neon sign designers call for a slightly wider type of letter, and this is more or less accepted as standard. The background letter is almost as wide as it is high, and the footage of such a letter can be safely estimated as being equal to three and a half times its height.

For double outline block letters, multiply the overall height by FIVE. Where the letters deviate from the block type, as described above, it is advisable to make a small scale drawing and measure double-outline letters with a map measurer, as any departure in the shape of the letter from normal practice will result in a much bigger alteration in the length of tubing. Naturally, for triple-outline letters the length of tubing is arrived at by adding five times the overall height of the letters for the outer lining to $3\frac{1}{2}$ times the height for the centre or inner lining.

Any deviation in style, such as square or futuristic block, should be subjected to the accuracy of the map measurer.

SCRIPT requires an entirely different method of calculation. Unlike block letters, all script wording, whether of names, slogans or messages, usually begins with a capital letter. These, therefore, must be measured separately.

Calculate *all* script lettering by multiplying the extreme over-all height of the letter—*measured on the slant*—by FOUR. The tail of the lower-case " p," or the loop of the " k " or " j " should not be included in the overall measurement.

As an example, take the words "Popular Café," in script characters. Let us assume that the capitals are 3 feet, and the lower-case 2 feet. A 3-feet *block* letter implies an overall vertical height of 3 feet. A 3-feet *script* letter also implies a letter having a vertical height of 3 feet, but the actual letter may be considerably more than this. Few script letters are written vertically, their chief effect being obtained by sloping them, with the result that by measuring a 3-feet (vertical) letter along its sloping dimension, it would probably be found that it was 3 feet 3 inches or so.

This, then, is the figure which must be multiplied by four to assess the footage involved—in this case 13 feet—for one ostensibly 3-feet letter.

The 2-feet lower-case "o" and "u," and the final "a" and "r" in "Popular," would actually be about 2 feet 2 inches each, *i.e.* 8 feet 8 inches of tubing for each letter.

The lower-case "p" and "l," although they are longer than for instance the "o," should be considered as being the same height, namely, about 2 feet 2 inches each and would require 8 feet 8 inches of tubing for each letter. Apply the same measuring process to "Café," and the result is at first sight surprising—104 feet of tubing, a seemingly impossible footage for such an apparently small sign.

Let us compare this with our neon-type block letters. For the same sign in 2-feet single-outline characters—the height of the lower-case script in the previous example—only 77 feet would be necessary, and even in 3-feet letters only 116 feet of tubing would be involved. That is why block letters are so much more in evidence—they are both bold and economical.

With block letters almost the whole of the tubing employed is used as part of the effect, whereas with script lettering a large percentage of the tubing is expended in doubling backwards and forwards around scrolls and returns. This doubling is necessary to the manufacture

of the sign, but when it is being erected only the face tubing counts and the rest must be blacked out. Script is admirable when used lavishly and in cases where a signature or similar device is required to be copied, but it has not the quick legibility of block characters, and is so much more expensive.

## § 36. *ESTIMATING THE JOB*

In the foregoing chapter, full particulars were taken of the site of the proposed sign, and from these particulars, and with the assistance and information supplied by the client, a scheme can be prepared. No hard-and-fast rules for guiding this part of the process may be given, as the scheme will depend on the client's purse, his ideas, and the scope provided by the site. When, however, the scheme has been prepared, an estimate can be drawn up, and upon this will depend the future of the sign—at least, so far as you are concerned.

In estimating, it is advisable to draw up a standard estimating form, on which are set out the name of the client, proposed site, materials to be used, terms of purchase, etc. This precludes any possibility of anything being overlooked, it remains as a record for your files, and adds system to the whole proceeding. Always estimate on cost figures, adding overheads and profits later.

Assuming this has been done, the first things to consider are the materials. The backing letters come first. These may be of wood, stainless steel or chromium-plated brass, etc. If of wood, teak will be used, and the finish must be decided. A two-colour finish will cost more than a single-colour, but if the job will stand the former, so much the better. The letter-maker will supply prices of his letters, or if they are made on the premises, the prices will be known.

The number of transformers will depend on the footage of the sign, and also whether it is for outside or inside use ; if outside, then 10,000 volt transformers will be used, and

for estimating purposes one transformer should be allowed for every 30 to 40 feet of tubing. The layout of the sign must be considered, however, and if it consists of a number of sections each containing, say, 20 feet, and each section separated from its neighbour, then a separate transformer must be allowed for each section, and its voltage will be about 7000. The transformers must be waterproof, and their cases strong enough to resist all weathers. For inside or box-sign use, small transformers of 3000 to 5000 volts will be employed. These operate from 9 to 15 feet of tubing.

The length of high tension cable required may be estimated on the site when the transformer positions are chosen. Allow 1 foot at each end for bending and connecting up, etc. For outside use, the cable should be lead-covered, and in some districts it is necessary to armour the cable. For inside use, rubber-covered cable is suitable, and this is also used for outside signs where the wiring is concealed either in the letters or behind the facia.

The number of supports for the glass tubing will depend to a large extent on the arrangement of the sign, and also upon the size of the sections. For estimating purposes, it will usually be found quite satisfactory to allow two clips or supports for every 3 feet of tubing, but where a glass panel sign or a box sign is being quoted for, then the number of supports may be estimated more exactly. Usually, each letter will require three to four supports if it is mounted separately with two electrodes, but if two or three letters are joined together, then five or six supports for the section will probably suffice.

The number of bell or pipe glasses may readily be determined from the number of sections of tubing, and a further two must also be allowed for each transformer, to protect the cable ends. These latter are usually spoken of as *H.T.* glasses, against *Bell* or pipe glasses for the electrode insulators. Do not estimate too tightly on supports or bell glasses ; generally it will happen that some get broken or lost.

The box for a box sign can readily be priced, as this is largely a standard article. If, however, a special type is wanted, then a sketch must be prepared and submitted to the box-maker. Neon box signs are usually made of lead-coated sheet-iron, sprayed white inside and black outside. The colour of the inside is of no importance, however, as the tubes, after all, are outside. The panel may be of metal or of wood, such as Masonite Presdwood. This, as already stated elsewhere, is eminently suitable for neon sign panels, as it can be finished in a variety of ways, and, in addition, is an insulator. Do not forget to use Tempered Presdwood.

To keep the price of a glass panel sign down to a minimum, reduce the number of holes as far as possible. Glass panel signs usually have the tubes mounted on their faces, with the electrodes projecting through holes in the panel. The diameter of an electrode clearance hole is generally 1¼ inches, and to keep the number of these down, make the sections of tubing as large as possible. In a sign having about 40 feet of tubing, arranged in two lines, four sections would be used, employing eight electrodes only. This arrangement makes the "transforming" somewhat simple, as one would be used for each line of wording. In getting a price for a glass panel, the number of holes must be specified and, consequently, the number of supports decided upon. It will, in the majority of cases, be found quite satisfactory if five supports are allowed to each section. This permits of two horizontals and three verticals, and will hold the tubes quite steadily and in proper alignment.

The wording of the sign may be written on the panel, or it may be sandblasted from the rear, and the sandblasted groove either painted in or left uncoloured. If painted, fit the tubing to the front of the panel, but where a cheap job is required and no painting or sandblasting is allowed for, then the tubing may be fixed to the panel from the rear. This method permits of a neater fixing, and in addition it cuts the cost of the panel, owing to the

fact that only a few very small holes are necessary. Glass panels are constructed usually of best quality plate, about ¼ inch in thickness, with their edges ground and polished. In general, the glass panel-maker will give a price for the job, including drilling and writing, etc.

Where the panel requires a frame, this is made from angle iron, unless instructions to the contrary are given by the client. A simple frame consisting of two runners, held apart at intervals with flat strips, and fixed to the wall with " U " irons, will be found quite satisfactory, and can be made in a very short time. Where the job will stand the addition, the estimate should allow for the use of galvanised ironwork, as the maintenance costs will be reduced and the appearance of the sign will not readily depreciate. The framework estimate should include any small items such as transformer supports, etc.

For large installations, to be fixed at some considerable height from the ground and on the top of buildings, etc., the design of the framework requires the services of a skilled steelwork designer. In these cases, if a rough lay-out of the proposed sign, together with a few details of the frame required, is sent to one of the steel construction firms, they will quote an approximate figure. A definite price for the steelwork for a very large sign is rarely called for straight away, as the ultimate design of the layout depends on so many factors. As a rough approximation, large framework may be estimated on the basis of £20 per ton, erected, but this figure does not include the supply or erection or removal of cradles, or the making good of brickwork.

Where the sign is inaccessible, some means must be provided whereby the maintenance engineer can attend to the sign. This provision can take the form of a steel ladder extending from a convenient window and fixed to the wall. A platform should be built behind the sign so that access to all parts is readily had.

Steel ladders can be bought ready made, the price of a 15-foot ladder, erected, being about £5 (not including the

supply of scaffolding, which must be arranged by the sign-contractor). The inquiry will usually state if any provision for maintenance must be made, and if this is omitted, a price for the steel ladder and platform may be included in the quotation as an extra.

With regard to scaffolding, some of the larger contractors have their own cradles and falls, etc., but these can be hired so cheaply that, unless a large volume of cradle work is likely to be done, it is better to hire them for each job.

When estimating, ascertain if cradles are likely to be required. It may be that although the sign is only about 30 feet up -a convenient ladder height—the client does not wish to have ladders used, or the local authorities forbid their use except in specified hours. In this latter instance, the specified hours are usually outside the normal working hours, and so cradles are the only solution. This adds materially to the cost of erection in quite another direction, namely, the erecting staff are able only to work at about half the normal speed, owing to the constant movement of the cradles, and the extra precautions which have to be taken by reason of their position. When compiling your estimate, therefore, allow of double-time for those workmen engaged on cradles.

Cradle-hiring firms are very moderate in their charges, and for one cradle to span a building about 20 to 30 feet in width, the charge will be about £4 for the whole job. This includes the erection of the cradle and gear, the hire of same, and removal when the work is completed.

The low tension material costs must include for the use of screwed conduit, a double-pole ironclad emergency switch (the Fireman's Switch), a double-pole ironclad fuse switch, and a distribution board with one way per transformer. A time switch may be required, and this should be of the mechanically or electrically wound type.

If the supply is Direct Current, a rotary converter must be included, together with starter. If a sign on D.C. is required to be time switch operated, and the size

of the converter is more than ·5 K.V.A., then an automatic starter must be included.

The power supply company of the district in which the sign is to be erected should be approached to ascertain if they require the correction of power factor to ·8, and if they do, then the estimate must allow for the necessary condensers. Most neon sign installations have a power factor of approximately ·4–·5, and it will usually be found quite satisfactory if a 10 or 15 mfd. condenser is allotted to each 10,000 volt transformer. When estimating the number and size of condensers for power factor correction, the voltage and frequency of the supply must be noted. The size of the necessary condenser varies inversely as the frequency of the supply, and directly as the square of the voltage. Put simply, this means that where a 15 mfd. condenser will be suitable for 250 volts, 50 cycles supply, a 7½ mfd. condenser will do the same work if the supply frequency is 100. Similarly, if the voltage is 100 instead of 250 and the frequency remains 50, the size of the required condenser will be 93·75 mfd.

If the supply is D.C. then it may prove to be more economical to correct the power factor to ·8 even if the power supply company do not require it, as this will allow the size of the converter to be reduced.

The estimate should include in some cases the supply and erection of the necessary gear to cut out interference with radio sets, but in general it is quite in order to leave this point until the client asks for its settlement.

The tube manufacturer will supply a price for the tubing, usually basing his charge on a footage rate. Thus it will be necessary to work out the footage in the sign, and for this purpose the information given on page 100 will be useful. Some tubing manufacturers will quote an inclusive price for the supply of tubing and transformers, and for the sign-contractor who has done only a small amount of neon work, this method is the wisest, as it precludes any possibility of slipping up over the matching of the transformers.

The whole of the materials have now been priced, and the estimate awaits the addition of erection charges, overheads, commissions and profits. The time taken to erect the sign will naturally depend upon too many variables to allow of any golden rules being laid down, unless, of course, a box sign or a number of box signs are the subject.

At the present time, the price of a neon sign of a more or less straightforward type, consisting of lettering and perhaps a little outline tubing, works out at between 15s. and 20s. per foot-run of tubing, erected complete with all high tension apparatus, but excluding the low tension wiring, time switches, flashers, rotary converters and the like, which are all extraneous to the high tension installation.

Glass panel and box signs of the straightforward type work out at about 13s. to 16s. per foot-run, and outlining at about 10s. to 12s. per foot-run. These prices are, of course, only approximate, varying with the job and manufacturer.

## § 37. *MANUFACTURE OF NEON TUBES*

*Historical.*—The first experiments on electric discharge in vacuum tubes were conducted at about the same time as the early experiments on vacuum pumps. In fact, the two were related in that a greater range of phenomena was obtained as the pumps became more efficient, and this led to greater efforts on the part of the pump engineers and experimenters.

In 1709 an Englishman, Hawksbee, delivered a lecture on the " Strange Effects produced when Matter is finely sub-divided in Vacua." This lecture, together with a demonstration, was the first real establishment of anything of importance in connection with discharge tube phenomena, at least in England or by an Englishman.

Hawksbee's early work was based on the observations of a Frenchman, Picard, who in 1676 wrote on the

luminous effects produced in the evacuated space of a barometer when the mercury was agitated, these effects being clearly seen in the dark. Hawksbee followed up these observations, and designed and produced a number of evacuated vessels in which mercury could be shaken or otherwise agitated; and the effects obtained, and which he termed "Mercurial Phosphorus," were similar to those obtained by Picard. He later came to the conclusion that electricity played some part in the performance, and accordingly evacuated a bell jar and applied a "static" electric charge to it. The appearance of a purple light in the jar showed him that his conclusions in this respect were correct. These experiments were amongst the first of their kind, and they therefore play an important part in the history of the discharge tube, and hence the neon sign.

The French were well to the fore at about this time, and in 1740 a Frenchman, the Abbé Nollet, produced what he termed an "Electric Egg." This was an evacuated egg-shaped vessel, and was charged by means of a frictional electric machine which introduced a static charge similar to that produced by Hawksbee. The results were similar in each case.

In 1795 Morgan terminated a series of experiments and declared that some relation existed between the pressure or degree of vacuum produced, and the nature of the discharge. He managed to evacuate a vessel to such an extent that a green fluorescence on the walls of the vessel resulted, and in some cases the vacuum was so hard that no discharge occurred.

Up to the early part of the nineteenth century the only available means for producing a high voltage were the frictional electric machines; and whilst they were successful in that they provided a sufficiently high voltage, this was only momentary and did not allow of any lengthy observations being made. Consequently, it was felt that a great deal of more useful work could be done if a continuous high voltage was available, and efforts were made

to develop this. This problem was, however, already on the way to solution, and in 1831 Faraday announced that his experiments showed him that, by means of electro-magnet induction, it was possible to obtain a very high output voltage for a very low input voltage. Moreover, this high output could be maintained more or less continuously.

This announcement was the first step in the development of the modern transformer and induction coil, but it was not until about 1850 that Rhumkorff, who had been working along similar lines, produced a really practical coil.

Meanwhile, in Germany, Geissler had been experimenting and had founded the basis of the modern discharge tube by sealing into the tube platinum electrodes. By means of the now established induction coil, Geissler, Plucher, Rhumkorff and others discovered in about 1860 that the discharge assumed certain definite forms under different conditions, and Gassiot at the same time produced a high voltage cell which gave him a continuous supply of 1000 volts, and corroborated these results.

After this, progress was more or less suspended until the advent of Sprengel's pump in 1865 and its application to discharge tubes in about 1870.

Subsequently the work of Hittorf, Goldstein, Müller and others was instrumental in discovering various laws underlying the origin of striæ from the cathode and the radiation stream from the anode.

Crookes in 1880 was responsible for the discovery of a dark space around the cathode, and later was able to use this discovery in research along lines suggested by Varley in 1870.

Faraday also, at about this time, noticed the other dark space characteristic of the discharge tube, and his name, together with that of Crookes, is at the present time associated with the various phenomena they were instrumental in discovering.

We have said that Geissler was responsible for the

first tube to be made on lines similar to those made at the moment, but it was not until 1893 that the discharge tube was considered as a possible illuminant.

At this time Moore started his experiments in the direction of artificial electric illumination, and, after eleven years of patient experimental work, in 1904 produced a complete installation which was carried out in Newark, New Jersey. This installation consisted of a length of 180 feet of tubing which was charged by means of a high voltage transformer. The gas inside the tube was carbon dioxide, and the glow which resulted from the application of the discharge was of a whitish-pink colour. Moore also tried filling the tubes with nitrogen, and with this gas obtained a golden colour. The main difficulty experienced in the use of these gases is that as the heat inside the tube increases, so the pressure of the gas falls off, caused by a chemical action between the gas and the material of the electrode. It therefore becomes necessary to provide a device whereby the gas can be replaced as it is absorbed, or as it " cleans up." The invention of the replenishing device is also due to Moore, and it is possible that this invention, intended originally as a supplement to the tube, is of more value to-day than the tube.

The year 1910 saw the introduction of the first Moore tubes in England, where they were used for the lighting of factories and offices. The Berlin Palace of Ice in Germany was also illuminated at about this time.

These tubes were filled with carbon dioxide which, as was stated, emits a whitish-pink glow, and are a very close approximation to actual daylight. They are in fact still used to a more or less limited extent for matching colours in textile and other factories, and in shops.

The necessity for providing the replenishing device in conjunction with the Moore tube rendered universal adoption of this form of illuminant rather expensive, and it was not until the advent of Rayleigh, Ramsey and Travers that the problem was overcome. Until then the only gases in use were carbon dioxide, nitrogen, hydrogen,

etc., but after considerable research and experiment the above three men managed, by fractional distillation of the air, to extract a group of inert gases : Neon, Argon, Helium, Krypton, and Xenon. These gases are exceedingly rare but not fugitive, that is, they do not clean up and disappear as do those used by Moore and his contemporaries.

The most generally used of these gases is neon, which, when used in the pure state, glows with a bright orange colour. The intensity of the glow from this gas is considerable.

Fleming was responsible for the introduction of neon to the service of radio. Bulbs filled with this gas were and still are used as oscillation detectors, and are found to be extremely reliable. They are also used to measure the wave-length of these oscillations.

The Moore tube as a display medium did not last for long. In 1910 a Frenchman, Claude, introduced tubes filled with neon for use in advertising, and the brilliant red and orange colours, combined with the much greater penetrative powers of these tubes, rendered them very effective.

This marked the commencement of a great deal of serious attention which it was destined would be paid to the neon tube as an advertising and display medium, and other colours of gases soon became available.

Various combinations of gases were found to give various colours, and the addition of mercury provided a still greater range. In addition, the use of coloured glass made possible the production of an almost limitless range of shades.

The chief disadvantage which attaches to the present type of luminous discharge tube is that the voltage required to initiate the discharge is so high, and experiments have been carried out for a number of years with a view to the production of a low striking tube. These have been produced, but their limitations are such that the high voltage tube still remains the most suitable.

## § 38. *CONDUCTION OF ELECTRICITY THROUGH GASES*

In order that the phenomena of the discharge in a luminous tube may be fully appreciated and understood, a knowledge of the atomic theory of matter and also the theory of electrical phenomena is essential.

The discharge tube was originally responsible for the early realisation of the fact that a material atom is built up of positive and negative units of electricity, and the identification of the negative unit with the electron.

At the present time we know an atom as consisting of a central and positively charged nucleus, surrounded by a group of negatively charged units or electrons which revolve and are arranged as a planetary system. The arrangement of the atom depends upon the nature of the material, in so far as the number of electrons per atom and the relative distance between the electrons and the central nucleus are concerned.

One important property of the atom with which we are directly concerned is that it is capable of absorbing a certain amount of energy, this energy being utilised in transferring an electron from its original position in the atom to a new position. The extra energy is said to " excite " the atom, and its return to the normal state by dissipating this energy is accompanied by the emission of electro-magnetic radiation.

For the sake of simple explanation, we will consider a tube fitted with an electrode at each end and filled with neon. A certain voltage is applied at the electrodes and under the influence of this voltage an electron is caused to move inside the tube. As it moves it is continually colliding with the atoms of gas, and the number of collisions per unit time depends upon the gas pressure, and hence the number of gas atoms present. Now the speed at which the electron travels, and consequently the energy with which it collides with the gas atoms, depends

upon the voltage or potential difference producing the movement, and, provided that the energy of the electron is below a certain amount, any collisions will merely result in the electron rebounding from the atom involved. This type of collision is known as an " elastic " collision, and no transference of energy takes place.

Provided the voltage is below a certain amount, only elastic collisions will take place. Now if the voltage at the electrodes is increased—thereby increasing also the velocity and energy of the electron - above a certain critical value, a collision between the electron and a gas atom will no longer be elastic, but will result in the whole of the energy of the electron being transferred to the atom. This will cause one of the electrons of the gas atom to be transferred from its normal path around the central nucleus, to a new path at a greater distance from the nucleus. The atom is then said to be " excited," and the voltage producing this state is known as the " excitation voltage."

The atom does not remain in the excited state, however, but returns to its normal condition when the energy which was forcibly imparted to it is dissipated, and, as previously stated, the dissipation of energy is accompanied by the emission of electro-magnetic radiation. If the wave-length or frequency of the radiation stream belongs to that portion of the spectrum to which the eye is sensitive, the return of the atom to its normal condition will be accompanied by a characteristic glow.

It should be noted that the atom absorbs energy in definite amounts, and if the colliding electron has an amount of energy slightly in excess of that required to excite the atom, it will rebound with this excess energy.

Similarly the dissipation of the atom's acquired energy follows a definite law which obtains for all atoms of a given element, such as neon, etc., and the released energy is emitted as radiation of a definite frequency.

The relationship between the energy and the radiation

frequency is one of the fundamental laws, and it states that the frequency of the radiation emitted is proportional to the energy dissipated by the atom during radiation.

The unit of energy is the electron-volt, and if we assume that the atom in its normal state has zero energy, then the frequency of the radiation is proportional to the excitation potential.

The law states :

$$\text{Energy } E = h \times \text{Radiation frequency } (v)$$

(where $h$ is Planck's universal constant and is equal to $6{\cdot}56 \times 10^{-27}$ erg seconds).

This can also be written as :

$$E_e = E_n - h \times v$$

(where $E_e$ is the energy in its excited state, and $E_n$ the energy of the atom in its normal state, which energy we have assumed to be zero).

The excitation potential is the lowest potential at which the energy of an electron will be transferred to an atom. If, however, the applied potential is increased to a higher value, the electron will have so much energy that instead of merely transferring one of the atom's electrons to a new orbit or path, it will cause the complete ejection of this electron.

Thus two new *ions* are formed, one the now positively charged atom—since it has lost an electron—and the other the negatively charged free electron ejected from the atom ; and the atom is then said to be " ionised." These ions travel amongst the other gas atoms with the velocity and energy acquired through the potential applied at the electrodes, and if the value of this is maintained at or above the " ionisation potential " of the gas atoms, the free ions will proceed to collide with other atoms and so generate more ions. These again will generate more, and so we have a continuous action of building up of ions, and the discharge is maintained in the manner we know so well.

At the commencement of this description, it was

assumed that an electron was moving inside the tube, and we have seen how this was responsible for the commencement of the discharge. Actually, of course, not one but many millions of atoms are behaving in precisely the same way, the additive effect of this more or less continuous action being the visual radiation associated with the luminous discharge tube.

It is, however, the initial movement of the ions which is responsible for the subsequent train of events described above, and were it not for the fact that there is passing between the electrodes a continuous stream of ions, even when no voltage is applied to the tube, we could not produce the " neon " tube.

This means that the two electrodes are not completely insulated, but are in fact connected just as surely as though with a copper wire. Further, it means that air is not a perfect insulator, and that even if a very small voltage is applied to two air-spaced electrodes a minute current will pass. The value of this current is too small to be measured directly, and it is only in connection with very high voltage work and with discharge tubes that the conductivity of air is of importance.

For a long time it was thought that air was a perfect insulator, and that the slight leakage of electricity which took place when a charged conductor was immersed in a gas was due to defective insulation of the supports or the presence of particles of dust in the gas. Later experiments showed that this leakage could not be prevented, and also that it varies with time and place ; for instance, variation in altitude, bright or foggy weather, etc.

It is now known that the conductivity of air is caused through the production of ions in the air by certain forms of radiation. If two air-insulated electrodes and the space separating them is exposed to the action of a strong electric field, on the application of a potential difference to the electrodes, the current passed will be greater than when the electric field is removed. Also, when the electric field is withdrawn, the air or gas will only slowly return to

the normal state, although this action may be accelerated by filtering the air.

The discovery that light, particularly the ultra-violet rays, causes ionisation of a gas, originated during the course of experiments on electric waves, when it was found that the incidence of ultra-violet light upon a spark-gap facilitated the passage of the sparks. The production in a gas of ions through the action of cosmic rays and other forms of radiation or radio-activity is known as " photo-electric " phenomena, or " photo-excitation." Thus, in our tube, the primary ions are caused through photo-excitation, and on the application of a potential to the electrodes, they pass an electric current which increases as the primary ions produce more ions, and these produce a still further number until the current passed attains its maximum value, and the tube becomes " alight."

The voltage required to start the discharge is the " striking potential," and the value of this may, once the discharge has commenced, be reduced without upsetting the performance of the tube.

If the flow of primary ions could be increased, then the striking voltage could be reduced, and one method of doing this consists in employing a " hot " cathode, instead of the " cold " cathode generally used. This will be discussed at a later stage, but it is of interest to note that if a small quantity of mercury is introduced into the tube, the striking voltage is reduced. This is due to the fact that the excitation potential of mercury is less than that of neon, and the primary flow of ions in the gas forms a number of excited atoms of neon which, by a radiationless transfer of energy, succeed in ionising the mercury. This produces, however, a blue tube, and is, therefore, not applicable to strictly " neon " tubes.

Conversely, the introduction of any means whereby the energy of the excited atoms is dissipated without ionising the gas atoms, necessitates the application of a higher potential to strike the tube.

The following table gives the values of excitation and ionisation potentials for a number of elements :

EXCITATION AND IONISATION POTENTIALS OF SOME COMMON ELEMENTS

| Element. | Excitation Potential ($V_e$). | Ionisation Potential ($V_i$). |
|---|---|---|
| Helium (He) . | 19·55 | 24·45 |
| Neon (Ne) . . | 16·6 | 31·48 |
| Argon (A) . .. | 11·6 | 15·53 |
| Hydrogen (H) . | 10·3 | 13·2 |
| Mercury (Hg) . | 4·9 | 10·4 |
| Nitrogen (N) . | 7·9 | 15·75 |
| Oxygen (O) . | 7·0 | 14·8 |
| Sodium (Na) . | 2·1 | 5·1 |

The discharge tubes in neon signs operate at a very high voltage, and this is produced by means of a transformer. The supply to the tube electrodes is, therefore, alternating, and the electrodes are consequently alternately Anode and Cathode. The anode and cathode characteristics of a *direct* current-operated tube are quite different, but the periodicity of alternation between anode and cathode with a neon tube for sign work is so short that due to persistence of vision the glow appears continuous.

When a direct current is applied to the electrodes of a discharge tube filled with a gas at a low pressure, certain well-defined characteristics are manifest. It will be observed that a dark space separates the light from the cathode, this space being known as a primary dark space. The cathode glow is a thin line of light of a reddish shade and separates the main cathode dark space from the primary dark space. Then comes the negative glow which

is orange and of a maximum intensity next the cathode, fading off into the Faraday dark space. The anode glow consists of a number of balls of coloured light spread over the surface of the anode, whilst between the anode glow and the Faraday dark space is the positive column, composed of a series of discs or striæ across the tube. These striæ have a well-defined blue edge at their negative faces, which merges into an orange glow at their positive faces.

The structure of the positive column—that part of the discharge with which neon signs are concerned—depends to a great extent upon the composition and pressure of the gas in the tube, also upon the type of current whether direct or alternating, and upon the electrodes.

If the tube is filled with a nominally pure gas to which later is added a trace of impurity in the form of another gas or vapour, the structure of the positive column will undergo considerable change. It is possible to split the positive column into a series of discs or striations which may either revolve about the axis of the tube or travel from the anode to the cathode. Again, the column may consist of one or more thin spirals which wind along the tube from one electrode to the other. These effects are caused by interaction between the gas and the impurity, and unless some means are taken to preserve the generation of the impurity, the positive column becomes a stable glow owing to the " cleaning-up " of the impurity by the gas. These effects are observed during the manufacture of the tube in the pumping process, and are due in some cases to the presence of moisture.

So far we have only dealt with the effects when the tubes are subjected to a direct current, but the same process is repeated when the current is alternating. In the latter case the polarity of the electric potential changes every half-cycle, and if the frequency of the supply is of the common 50 cycles, it means that the above phenomena will change every 1/100th second. In other words, the glow will cease and the phenomena will be repeated—but from the opposite end of the tube—100 times per second.

The eyes, of course, owing to persistence of vision, are not able to detect this rapid change from light to dark, and the tube appears to discharge in the same manner at each end.

When a tube containing a mixture of gas and impurities is subjected to an alternating current supply, the effect on the positive column is to produce some very wonderfully varied and animated coloured striations and streams.

## § 39. *STRIKING POTENTIALS*

The striking potential $V_s$ of a gas is the lowest potential at which the tube will preserve a self-maintained discharge, or, in other words, the lowest potential at which the tube will strike. According to Paschen, the value of this potential is dependent only upon the volume of gas between the electrodes. This is correct, provided that other considerations such as electrode shape and material, tube geometry and external circuit conditions are the same.

We have shown, however, that $V_s$ is very critical and is affected by very small changes in these considerations.

The value of $V_s$ can be lowered in a number of ways, and similarly can also be increased. If the electrode is subjected to a stream of ultra-violet rays from some external source, photo-electrons are liberated from the electrode metal, and the discharge is thus given an impetus. Another way of lowering the value of the potential necessary to strike is to introduce into the gas another gas or vapour which has a lower ionisation potential than the original gas. This added gas will ionise at a lower voltage and will help to produce a higher rate of discharge of the original gas.

If, however, the applied voltage or potential $V_a$ is lower than $V_s$ by only a small amount, the tube will strike, but only after an appreciable lapse or "time lag," the value of which will depend upon the difference in potential between $V_a$ and $V_s$.

## § 40. *HYSTERESIS*

It has been shown that the discharge in a gas-filled tube, once it reaches the stage where it will be self-maintained, is of such a form that ionisation of the gas increases, so much so that this discharge may still be maintained but at a much lower potential. Once the self-maintained discharge occurs, it may be continued by a lower voltage until the value of this voltage reaches the extinction-point and is then equal to $V_b$. This effect is known as Hysteresis.

Hysteresis can be demonstrated by means of a small discharge tube, and the characteristics are as follows :

The tube is connected to the supply source in series, with which is a resistance, so that the value of the voltage may be altered. The increase in the current will at first also be gradual and more or less in direct ratio to the voltage. This continues until the ionisation potential is reached, after which there is a big increase in the current for a slight or negligible increase in the voltage. The voltage may then be reduced and the current will again be reduced in direct ratio until a point occurs, the value of the voltage at this point being $V_b$, when the current will drop without any appreciable alteration of the voltage. This characteristic is known as hysteresis loop and occurs frequently in discharge tube phenomena.

A practical demonstration of the hysteresis loop is given in an apparatus used to test condensers.

The condenser is connected in parallel with a discharge tube or lamp and a battery or other current source. A switch is also included, so that the battery can be connected or disconnected at will. The voltage of the battery is less than the striking potential $V_s$ of the tube or lamp.

Now, if the switch is thrown so that the circuit is closed, a current will flow into and charge the condenser. When the value of this charge reaches the striking potential $V_s$ of the tube, the discharge will take place and

will continue under the decreasing voltage until the extinction voltage $V_b$ of the tube is reached. The discharge will then cease, and the condenser will again build up the voltage to $V_s$, when the process will be repeated.

The frequency of the oscillations gives an indication of the capacity of the condenser.

A device of this description may successfully be used as a neon sign flasher, and the capacity of the condenser should be such that it will function as required under the operating voltage of the sign.

## § 41. *THE COMPLETE CHARACTERISTIC. VOLTAGE-CURRENT RELATION*

A complete understanding of the complete voltage-current relation of a discharge tube involves a very complicated process which is not of very great importance to us as sign manufacturers. In so far, however, as it provides us with a more complete knowledge of discharge tube phenomena, it is desirable that we are acquainted with the general principles, and these are given herewith.

There are two points which are of primary importance in considering the voltage-current relation. In the first instance the discharge between the electrodes is not uniform, but is composed of two parts which are not directly related : the positive column, which provides the glow, and the glow around the electrodes. In the second instance, although the tube—or rather, the gas—is a conductor of electricity, it does not obey the same laws as does, for instance, a copper conductor. That is, it does not obey Ohm's law, and the voltage, current and resistance are not proportional.

We will assume that the tube under observation is free from any external source of radiation which may tend to produce an initial discharge, and hence an initial passage of current other than that normally present. It will be seen that if we were to totally screen the tube from outside

radiation of all description, a discharge could not be produced, but the observations are based on the assumption that the number of primary ions is not greater than that usually present.

When a gradually increasing potential is applied at the electrodes of the discharge tube, there will be a very slight passage of current until the potential reaches the striking-point, when it will be equal to $V_s$. Now if we trace the voltage drop between the electrodes, we find that there is a sharp drop at the cathode—the negative electrode—whilst the drop over the positive column is more or less uniform. The positive column characteristics do not, however, obey Ohm's law, but we find that after $V_s$ is passed the voltage drops whilst the current is increased until a certain point is reached, when both the voltage and current increase. Meanwhile, a very faint glow on the cathode will be apparent when $V_s$ is reached, and as the voltage is increased this glow will spread, until it finally covers the whole surface of the cathode. It is from this point that the voltage remains practically constant whilst the current is increased, when a further increase in voltage causes the cathode drop to increase, and hence the voltage drop across the whole tube increases, accompanied by an increase in current. If this is continued, the cathode becomes hot, and the discharge no longer takes place in the form of a glow, but changes to an arc discharge which ultimately will result in the fusing of the electrodes.

When the tube is operating under normal conditions the cathode glow does not entirely cover the surface of the cathode, and the intensity of the light produced up to this point is proportional to the current passing.

It will be noted from the above description that the glow occurs on the surface of only the cathode, but with a 50-cycle alternating supply—the cathode and anode changing every half-cycle—owing to persistence of vision the glow will appear continuous over the surface of both electrodes.

## § 42. *PRACTICAL APPLICATIONS OF THE DISCHARGE TUBE*

It is now being fully appreciated that the field in which discharge tubes can be used is practically unlimited. They are being used for a multitude of different purposes, and their uses are continually expanding to other branches of science and industry.

We will for convenience divide these gas discharge tubes into two groups at the outset, and, should it be necessary at a later stage, will include any special types which may crop up in a separate or experimental capacity.

The two main divisions are :

1. Small negative glow tubes or lamps ; and
2. Positive column tubes such as " neon " tubes.

It is usual to speak of " negative " tubes when reference is made to tubes in which the electrodes are very close together and the glow is mainly from the cathode. In these cases the anode and positive glows are almost negligible.

We have seen from a previous paragraph that when the tube is operating under normal conditions the cathode glow does not entirely cover the cathode, and further, that under these conditions the extent of the glow or, what is the same thing, the intensity of light resulting from this glow is proportional to the amount of current passing.

It is on this principle that a number of types of tube are based, one particular instance being the tube used in early sound recording for the " talkies." Any variation or fluctuation in the input current from the amplifier caused a variation in the area of the cathode covered by glow.

The tubes used for this work were mounted in a manner similar to that used for mounting household lamps, and were designed to plug into a standard socket. The operating voltage required for a tube of this description is the normal mains voltage of 200/250. The tubes are filled with a mixture of Neon and Helium, and the

pressure of this gas varies according to the particular uses to which the tube will be put.

The Osram Company introduced some time ago lamps which they termed "OSGLIM" lamps, and these lamps, which are filled with a mixture of Neon and Helium, are used for indicators, pilot lights and a multitude of other purposes.

The first of these lamps is the OSGLIM Beehive lamp. This is about the size of an ordinary electric household bulb, and the electrodes are in the form of a spiral of wire and a flat plate respectively. They are used to a great extent as nursery lights, pilot lights for radio sets and for general testing purposes. Due to the very low power consumption by these lamps they are used and kept burning for hours, and afford a permanent indication of trouble or lack of trouble, as the case may be.

The second of the OSGLIM series consists of a similar-sized lamp, but in this case the electrodes are in the form of a letter or number. The letters or numbers, which are mounted in the inverted position in the bulb, provide a very striking display when they are illuminated. Words can be built up by various groupings of the letters and an effective advertising display so formed.

The third of the series is intended as an indicator lamp and has the electrodes in the form of a ring and a plate respectively.

The first two lamps are designed to operate from 200/250 volts and they consume approximately 5 watts each.

The third type operates from a similar voltage, but is divided into a large and small lamp, the consumption of the smaller being 0·5 watts and that of the larger 5 watts.

The striking voltage of these lamps is about 180 watts and the extinction voltage 140.

In technical terms :

$$V_s = 180 \text{ volts D.C.}$$
$$V_b = 140 \text{ volts D.C.}$$

Another type of lamp is that in which the electrodes are " U "-shaped, the idea being to concentrate the discharge in a very small area so that the lamp may be used for spectroscopic research.

These lamps may be filled with almost any gas or combination of gases, and are made of quartz or with a quartz window so that the passage of ultra-violet rays from a mercury lamp is not hindered.

Lamps having a large flat plate are used to a great extent for television. The intensity of the glow scanned at any instant by the scanning disc of the apparatus is a measure of that element of the object or picture.

This lamp is also used for the reproduction of sound in talking films. The glow from the tube, which is varied or modulated by the microphone, is projected onto the edge of the film as it passes through the recording chamber, and the varying intensity of the line which this glow causes to be recorded on the film can be interpreted in terms of the sounds producing the modulations at the receiving end.

The type of tube for this work is of a more specialised nature than the OSGLIM. Due to the fact that neon is almost photographically non-actinic, that is, the glow from a neon tube will not greatly affect a sensitive plate, this gas is not used as a filling for sound-recording tubes.

The General Electric Company have developed a lamp for use with sound-recording apparatus which gives a very intense and highly actinic light. This is obtained by the use of a Neon-Helium mixture and a small positive column inside the tube.

Other tubes of the negative glow tube are to be found throughout the electrical industry. Safety devices, voltage regulators, warning devices and insulation indicators are a representative few and do not by a long way exhaust the list.

## § 43. *POSITIVE COLUMN TUBES*

Positive column tubes may be divided into two classes, namely, cold cathode tubes and hot cathode tubes. Cold

cathode tubes may be referred to as high tension tubes, and they are the type which is used for advertising and general display work, and known as " Neon " tubes. We are mainly concerned with this type of tube, so that if we discuss first the hot cathode tube, we can devote the rest of the available space to the neon tube.

## § 44. *THE HOT CATHODE TUBE*

The neon tube, employing as it does a cold cathode, has small brilliance, but is nevertheless eminently suited to its purpose in that the source of light—the tube itself—is actually the sign or the message which it is desired to convey. The tube is not an illuminant—unless in the strict sense of the word—as it does not call attention to surrounding objects by flooding them with light and so making them stand in relief, but calls attention to itself as the object. In other words, the *source* of light is employed, instead of the light only, as is the case with more usual methods of illumination. Where the light and not the source is the main requirement, the cold cathode neon tube has not up to the present been employed to advantage. The light given from a tube increases as the current increases, but with the cold cathode tube there is a certain relationship between the area of the cathode and the current passed, which is a factor determining the life of the tube. If the current passed is greater than that which the relationship allows, then the life of the tube is correspondingly shortened. Thus to preserve the same period of useful life, the area of the electrodes must be increased if an increase in light is required. Here, however, we meet a serious snag. The brilliance required must be at least 20 times that of the usual sign tube, and for more general application should be up to 100 times as great. This means that the area of the electrodes will have to be embarrassingly large, and so cold cathode " illuminating " tubes are largely out of the question.

A further drawback is the voltage required to operate

the tubes, and the solution lies in the provision of a tube which will pass heavy currents with small electrodes. As the current increases the voltage across the tube decreases, so that both current and voltage difficulties should be solved.

The life of the electrode, or more correctly the gas in the tube, is affected by the cathode drop, and the greater this value the shorter will be the life of the gas. It should be mentioned here briefly that, due to the bombardment of the electrode with positively charged gas ions, the electrode is caused to deposit a metallic film on the glass surrounding it. This film traps atoms of gas against the glass, with the result that the pressure of gas drops until a much higher voltage is required to strike the tube. This phenomena is known as "sputtering," and the higher the cathode fall the more rapid is the sputtering of the electrode.

We have seen that the prevention of the disintegration of the electrode—and the consequent trapping of gas which is entailed—is one reason why a heavy current cannot be passed by a cold cathode tube, and also that this disintegration or sputtering is related to the cathode fall. Thus if we can produce a tube having low cathode fall electrodes, part of the difficulty will have been solved.

One method is to heat the cathode to such a temperature that it will freely emit electrons, when a comparatively small voltage is required to strike it. This is the method generally adopted at present, and it explains the term "hot cathode." The method of heating may be either direct or indirect. In the first instance the electrodes consist of spirals of wire similar to a normal filament and connected across the heating supply, whilst in the second instance a spiral of wire is situated in close proximity to the electrode, which may be a cylinder, when the spiral of wire would be inserted therein and heated independently of the electrode circuit, in a similar manner to indirectly heated radio tubes.

An electrode heated in this fashion will have a drop

in the region of 20 to 30 volts, so that heavy currents can be made to pass without damage to the electrodes. Also, the passage of a heavy current causes a fall in the voltage across the tube, with the result that in many cases direct operation from the supply mains is possible. The tube will not, however, strike direct from the mains, but requires starting by means of a small high-frequency coil. This coil is incorporated in the circuit so that it is brought into action automatically when the current is switched on. When the tube starts, the coil is tripped out of the circuit.

Various gases and vapours are used for hot cathode tubes intended for general lighting purposes, and amongst these neon, helium, mercury, sodium and magnesium may be mentioned. So far, these tubes have proved moderately successful, but much still remains to be done before the colour problem is satisfactorily solved and colours suitable for varying purposes produced. With regard to the lighting efficiency of hot cathode positive column tubes, sodium tubes giving as much as 60 to 70 lumens per watt have been produced as against about 15 lumens per watt for the normal tungsten filament lamp. Sodium vapour, however, emits a yellow light which produces rather extreme colour distortion, and is, therefore, suitable only for very special purposes, or where the colour is of comparatively small importance.

In general, hot cathode tubes are showing themselves to be amenable to development, and the field for progress is wide whilst the immediate obstacles seem to be more or less readily surmountable.

## § 45. *MANUFACTURING SEQUENCE*

The neon sign commences its being in the drawing office, and the layout is sent into the glass-bending shop. The glass as it arrives from the makers is given a primary clean, both inside and outside, and the tubing is then bent according to the templates or layouts. After bending, the inside of the tubes is given a thorough washing,

the electrodes are joined on, and the tubes are then ready for fitting to their background. If the fit is quite correct, the tubes enter the pumping and filling bay, and after processing they are sent to the ageing bay. When they have been aged for a certain period, transformers are matched to them, and after any necessary blacking-out has been done, they are ready for dispatch.

## § 46. *PREPARATION OF TEMPLATES*

The neon tube bender does not work to a scale drawing of the finished article, but to a full-sized template. The nature of the work, and the shape to which the tubes have to be bent, do not allow of the use of scale drawings. The templates are prepared on either brown kraft or, if a number of sections or letters of the same shape are required, asbestos paper. The tubing is bent so that the front or face is flat, with the electrodes projecting to the rear, so that the templates have to be prepared in reverse. This allows the bender to lay the tubing flat on the template so that he may correctly follow the lines, and ensure that it will fit correctly into or onto its background.

The draughtsman usually works out the number of sections into which a sign has to be divided, and the bender merely works to the template. The number of sections is generally determined by the exigencies of the job. For instance, if the tubes were to to be fitted into recesses cut in the faces of metal letters, each neon letter would have to be a separate unit, *i.e.* provided with two electrodes. Cross-over pieces between two or more letters are in such circumstances not allowable, and even if the letters are only 4 inches in height, they must be separate or the appearance of the job will be spoiled. Where the tubing is to be superimposed on the background letters, then two or more neon letters may be joined together, and the cross-over pieces painted out with a colour to match the background. With border or outline tubing, long lengths may be made, and the limits to these lengths can

be decided according to the transport of the tubing, and the accessibility of the site. Thus, where 11/12 mm. tubing is used, the length of the section would be from 5 to 6 feet. This is quite a useful length, it is easy to handle, and can be transported fairly readily without fear of breakage. With larger diameter tubes, longer lengths may be employed owing to the increased stiffness of the tubes. The capacity of the pumping plant often sets a limit on the length of tubing forming one section, and as a general rule it will be found that the average plant can tackle sections of not more than 15 feet much more successfully than sections of 20 to 25 feet.

## § 47. *WASHING THE GLASS*

The glass tubing arrives from the makers in lengths of about 5 feet. These lengths or "canes" are in most factories given a primary wash both inside and outside before the glass bender works on them. The canes are first allowed to soak for a period of from ten minutes to an hour in a solution of nitric or hydrofluoric acid, the acid being put into a lead-lined container. The most efficient acid is hydrofluoric, and a solution containing about 5 per cent. acid in water will thoroughly remove all grease and dirt from the tubes if they are allowed to soak for about fifteen to thirty minutes. Hydrofluoric acid attacks glass more or less rapidly, and for this reason is contained in a gutta-percha bottle. The solution must not be too strong, and the period of soaking too prolonged or the inside of the tube will become etched. Nitric acid is almost as good as hydrofluoric, and it has the advantage that it is somewhat easier to handle.

When the tubes have received their soaking treatment, they are removed from the acid and well rinsed in distilled water to remove all traces of acid. In some cases it is advisable to give two rinsings with distilled water, the final rinsing of one tube being used as the initial rinsing for the next. The tubes should be placed in a bath containing

distilled water, or the water may be run through them by some form of circulatory system.

After rinsing, the tubes are ready for drying, and this is effected by blowing hot air through them. The hot air must be well filtered before being passed through the tubes, and the filter may take the form of glass-wool or some absorbent chemical. There are a number of absorbent chemicals in use, and in some cases these may be dried out and used repeatedly.

Proper cleaning of the glass tubes is essential if a long life is the desired end. Tubes which have been improperly cleaned soon cause the glow to lose some of its effect, and in time a flickering sign will result. The effects of faulty cleaning are not always immediately apparent in the finished article, and so, if maintenance charges are to be kept low, the tubes must be thoroughly processed.

It is advisable to rinse the tubes out after they have been bent, and before the electrodes are sealed on. This removes any small particles of glass which may enter the tube during bending, and also any moisture which may result from blowing. After rinsing, the tubes are dried with hot air as before.

## § 48. *GLASS BENDER'S EQUIPMENT*

The first and most important item of the glass bender's equipment is the heat treatment apparatus. In order that the glass may be bent, heat must be applied for softening purposes.

The various processes through which the glass passes from the " cane " to the pumping stage require the use of various types of gas fire.

For soda glass, such as is used almost universally in England, a mixture of coal-gas and air is used, and we will commence with a description of the burners or fires using this mixture.

For the bending of small or medium-size letters, and

also for sharp corners on ornamental work, a blast burner or cannon fire is used, and this may be of the single or double type. This is almost self-explanatory, and means that in the first case a single large or small burner is indicated, and in the second case, the instrument is complete with one large and one small burner, either being brought into action by a rotary valve, at the discretion of the operative.

The gas and air enter the burner by means of two independently operated or adjustable taps so that the required degree of heat may be easily obtained. The two components then pass into the mixing chamber and are led out at the jet. Burners may be obtained in which the gas and air are automatically regulated from one control, but these do not provide the wide range of flame necessary for neon tube bending.

The jet of the burner may be of a number of forms, and one very commonly used type consists of a length of longitudinally perforated glass rod. This has the advantage of cheapness, and is also very easy to replace, as it is held in position simply with a piece of thin paper twisted around it.

The barrel of the burner, at the outer end of which is fitted the jet, is fitted by means of lateral pivots to a crutch stand, and this stand is then fitted to the main stand so that it is free to rotate about a vertical axis. In this way the burner is completely orientatable and greatly facilitates the work of the bender. The air and gas are led to the instrument through the base of the barrel.

Where long lengths of tubing have to be bent into "slow" or gradual curves, the local heat provided by the cannon fire is useless, and for this work a "ribbon" or "manifold" burner is used.

As before, the gas and air are led to the instrument and controlled in the usual manner. The actual burner in the case of the ribbon burner takes the form of a horizontal cylinder or rectangular tube having the jet opening along

the top, so that when the gas is ignited a vertical flame running the whole length of the burner is obtained, and the glass bender is able to heat a length of tube equal to the length of the burner. Further, the whole of the glass is heated at an equal rate. The manifold burner is very similar, but in this case is composed of a number of separate small burners disposed close to each other so that a continuous flame is obtained.

Ribbon burners and manifold burners are obtainable in lengths of from 2 to 48 inches, and in the case of manifold types may be either curved or straight.

These types of burners do not give a very intense fire, and where a wide intense flame is required, a "Fishtail" burner is used. They are very similar to the ribbon burners, with the exception of the heat intensity, but are made in sizes only of from 1 to 4 inches. An alternative name for a fishtail burner is a "Batwing" burner.

In addition to the cannon and other bench burners (the burners described are *bench* burners), the glass bender requires a large and a small burner or "torch." Hand torches may be either single or double. A single torch has only one barrel and jet, whilst a double torch has two jets diametrically opposite.

Hand torches are used for general small work where it is required that the operator shall be able to manipulate his instrument quickly, and also for work which cannot be done by a bench burner. For instance, he may find that his tubing does not quite fit the layout, in which case he lays the work on his bench and makes the necessary alteration by using his hand lamp.

Where double torches are provided, the glass bender can heat all around the tubing by moving the torch through only one-half of a revolution. In this way much time is saved and in addition the glass is heated at a more uniform rate. Double torches are not, however, used to any great extent, as the single torch is found to be more practicable. Some bench burners have two or more jets

concentrating on a central point, usually the centre of the circle around which the jets are placed. Bench burners having more than one jet playing on the one point are known as " cross-fires " or " cross-cannons," and are used for electrode making and also for the bending of lead glass, as these operations require that work be held in the tip of the flame.

Most types of burner are designed to operate at a more or less standard pressure of gas and air. The air pressure varies from 2 to 3 lb. per square inch, whilst the gas pressure varies from 10 to 13 inches of water.

In the olden days of glass-blowing—and indeed there are at the moment a number of old-established blowers adopting this practice—the required air pressure was obtained by means of foot-operated bellows. This resulted in a very uneven pressure, unless a " balancing " tank was employed, but it has now been superseded by the motor-driven pump or compressor.

The compressor is usually driven by an electric motor and may be of either the reciprocating or rotary type. Of these two the latter is the quieter in operation and the more efficient. The air from the compressor is taken to a large tank or " balancing " tank, and the pressure in this tank is maintained above a certain level by means of an automatic cut-out and cut-in valve which controls the stopping and starting of the motor when the pressure in the tank reaches a predetermined figure. The burners are thereby supplied with air at a uniform pressure, the pressure being adjusted by means of a stop-cock and manometer on the tank.

Where only a few benders are employed, the gas at mains pressure will usually be found suitable, but in cases where there are a large number of benders the gas pressure has to be increased, and this is done by means of a gas " booster." This booster is similar to the rotary air compressor, but has in addition an automatic pressure regulator. Here again the gas is taken to a balancing tank, so that a smooth supply is fed to the burners.

## § 49. *GLASS BENDING*

The glass tubing from which neon signs are made may be either of soda, lead, Pyrex, or boro-silicate. Soda glass is used more than any other in this country, as its characteristics render it particularly suitable for the English climate. Lead glass is used largely in America and to some extent on the Continent, and is also used in England for the manufacture of electrode accessories, etc. Soda and lead glass are worked with the aid of coal gas and compressed air, but Pyrex and boro-silicate require oxygen and coal gas. These are silica glasses and are extremely hard and tough. They are used by only a few firms in England, and are somewhat easier to work than the softer glasses due to the wide range of temperature through which they remain pliable. Correctly treated, Pyrex is very strong in service, but after a time it becomes somewhat brittle unless carefully treated before erecting.

Thermal strains are not so important in Pyrex glass as they are in soda glass, a further feature of the easier working of the former.

There has been some effort on the part of Pyrex and other hard glass users to praise this material against the soft glasses, but the fact remains that any advantages which the hard variety may possess over the other are strictly dependent upon the correct treatment of the glass. During bending, thermal strains are induced in the tube, and unless the glass is properly annealed during or after working, these strains are not eliminated. If a section of strained glass is fixed in position on the job, it may quite easily remain intact for some considerable time, but when any sudden changes in temperature are experienced, the glass is initially handicapped to cope with the extra strain, and it collapses. Now with the soft glass, it is a simple matter to completely remove all strain whilst the tube is in the shop, by heating it slowly to a temperature of about 450 degrees C. and allowing it to remain at that temperature for a few hours. The hard glasses, how-

ever, have a much higher melting temperature, and it is impossible in some cases to heat the glass to a temperature high enough to remove all strain, or to keep it at a reasonable temperature for the required time. Unless the correct temperature is maintained for the proper length of time, the strains will not be removed, and will show themselves later in the form of a broken tube.

Strains in glass tubes are determined by means of polarised light. An incandescent-light bulb is mounted behind a diffusing screen and the rays from the screen are plane polarised by reflection at a black mirror. An analysing prism or eyepiece is attached at one end of the instrument, and the glass tube is held in such a manner that the rays of polarised light from the mirror pass through the tube being inspected and the eyepiece. The analyser is set to extinction, and the parts of the tube which are unstrained appear a uniform grey, whilst the other parts appear tinted with different colours according to the extent of the strain.

The manipulation of glass tubing requires considerable practice, and although the general principles can be laid down, it cannot be learned by reading.

The glass bender's kit consists of a bench burner, hand torch, tweezers, glass-cutting knife, one or more reimers and a charcoal pad about 3 by 2 inches.

The first operation is to cut off a piece of tube to the required length. Take a " cane " from the rack and hold it in the left hand. Taking the glass knife in the right hand place the thumb of this hand under the tube and draw the knife across the tube on the top. This will produce a scratch. Now hold the tube in two hands so that the thumbs are touching, their tips being directly below the knife scratch, and pull with a circular motion, using the thumbs as pivot. The tube will break cleanly across.

Where large diameter tube is being used, this method of cutting will not do, and the following should be used :

Take a piece of stout wire and bend a semicircular loop in one end of a diameter equal to that of the tube to be

cut. Place this in the flame, and whilst it is heating make a mark on the glass with the knife. When the wire is hot, place it around the tube so that the scratch is directly above, and slowly rotate the tube. This will result in a circular crack and will allow the tube to be cleanly broken by pulling as before.

A further method is to make a scratch in the required piece, and then place the red-hot tip of a piece of scrap glass on the tube opposite the scratch. The result will be as before.

When using a burner, remember that the hottest part of the flame is that just outside the darkly coloured section. Between this point and the burner is unburnt gas, and towards the tip of the flame is completely burnt gas. The inner portion will not heat, and the outer will make the tube black with carbon.

The intensity of heat can be varied by using more or less air or gas, and a flame should be chosen which is as hot as required but without roaring. Excessive roaring indicates too much air.

Take a piece of glass tube and hold it with the left hand between the first finger and thumb so that the hand is beneath. Steadying the tube with the fingers of the right hand, hold it in the flame and rotate it slowly by movement of the left-hand fingers. When the glass becomes soft, remove it from the flame and, still rotating, draw the hands slowly apart in a straight line. If this is done properly a part of the tube will possess a reduced diameter. This is known as "drawing down," and a measure of its efficiency may be obtained by seeing if the centre lines of the three sections are all in the same straight line.

To join together two pieces of tubing of the same diameter, cut off two pieces of the required length in one of the ways described above. Place a cork in the end of one piece and hold this in the left hand. Taking the other piece in the right hand, place the two ends to be joined in a cool part of the flame so that they are gradually heated,

and slowly bring them to the hottest part. During the time that the glass is in the flame it should be rotated slowly.

As the ends get soft it will be noticed that the diameter decreases and that the glass increases in thickness. When this happens, gently touch together the two ends and keep in the flame whilst continually rotating, taking care to rotate both pieces at the same speed. When the joint gets thoroughly soft, remove from the flame and blow gently into the tube until a small bubble appears at the joint. As the glass cools, gently pull the two ends apart until a single tube of uniform diameter and thickness is obtained. If there are any signs of a crack between the two pieces, repeat the process of heating, blowing and pulling.

To bend a piece of tubing. Take a piece of tubing in the manner described for drawing down, cork the left-hand end and hold it in the flame, rotating all the time, until the diameter where heating is taking place decreases, showing that the glass is thickening. When the tube becomes so soft that it is difficult to hold, remove from the flame and slowly bend to the required angle. As the glass cools, place the open end of the tube in the mouth and blow gently. This will prevent sagging of the walls and will result in a perfect bend.

Glass bending requires a considerable amount of practice before accurate bends can be produced.

To seal off the end of a piece of glass tubing, hold a piece in the left hand and place the end of the tube in the flame. Taking a pair of tweezers with the right hand, wait until the glass gets soft and draw it down at the end. Return the glass to the flame, wait until the end again gets thoroughly soft, and remove as much as possible of the drawn down portion. When this has been done, you will find that you have the tube closed at one end with a thick glass base. Return the tube to the flame, and when soft gently blow into the other end after having removed from the flame. As the glass cools, gently flatten out the end by applying the charcoal block.

To make a mitre joint such as is used for neon signs, seal off the end of a piece of glass in the manner described above. Now take a hand blow-lamp or torch and direct a thin pointed flame onto the wall of the tube at a distance of slightly less than its radius from the sealed end. When the heated portion becomes soft, blow gently into the other end of the tube, and a small pip should result where the tube was heated. Return to the flame, and when again soft, blow smartly through the open end, and it will be found that the glass forming the pip comes out in a very thin cloud which bursts with a pop, leaving a slight hole with a flanged rim around it. Direct the torch onto this rim and when soft open out the hole with a reimer until it is slightly smaller than the diameter of the glass tube, care being taken to see that the flange remains on the outside of the tube.

Next cut off a piece of tube and, taking this in the right hand and the sealed end tube in the left, place both in the flame of a bench burner and rotate until soft. When this state is reached, gently touch the two ends together and, still rotating, allow them to remain in the flame until the glass thickens, when the now single piece of tubing must be removed and gently blown into (the end of the sealed-end tube having been corked before placing in the flame) in the manner described for joining two pieces together. Here again as the glass cools gently draw the right-hand tube away from the other until perfect uniformity is attained. If necessary return the tube to the flame and repeat. When heating tubing which is not straight, such as a right-angle bend or mitre joint, always rotate the tube about the axis of one of the legs. This greatly facilitates the operation and prevents twisting as the glass becomes soft.

## § 50. *PUMPS AND PUMPING*

Pumps used for the manufacture of neon signs are usually of the two-stage rotary oil-sealed type.

The pump consists of two pistons which revolve

eccentrically inside two cylinders, the diameter of the cylinders being appreciably greater than the diameter of the pistons.

Set diametrically across the pistons are two blades, one to each piston. Imagine these blades as having been cut in two pieces and joined together again by means of springs. When the blades are in position across their respective pistons, the connecting springs tend to force the halves against the walls of the cylinders and thus promote an airtight joint.

The axes of the two pistons are in the same line and they revolve in the same direction and at the same speed. The two cylinders are connected to each other by means of a small passage.

The front cylinder connects with the tube to be pumped and the rear cylinder connects with the atmosphere through a spring valve. The pump is rotated by a motor, and due to the eccentricity of the piston and cylinder the space between these two is not equally divided by the blade. Air is therefore sucked through the inlet tube into the front cylinder and is forced along the passage connecting the front and rear cylinders. In the rear cylinder a similar action obtains, except that the air is sucked in through the connecting passage and is, therefore, that which is expelled from the front cylinder. This air is then expelled from the rear cylinder through the spring-loaded non-return valve.

The above described moving parts are built in the form of a unit, and this unit is immersed in a metal case filled with vacuum oil in order that an effective seal may be secured. The inlet to the pump, that is, the tube to which the vessel to be evacuated is connected, projects above and clear of the oil. The non-return valve is immersed in the oil and the escaping air bubbles through into the atmosphere.

From the description above it will be seen that the inside surfaces of the cylinders, and in fact the whole of the moving parts of the pump, must be kept in the best

possible condition if a high degree of vacuum is to be secured.

As the air evacuated from the neon tubes and other vessels come into direct contact with the working surfaces of the pump, all foreign matter must first be extracted. By foreign matter is meant moisture—which would in time corrode the cylinders—and other substances.

Moisture is extracted by placing a dehydrating trap in the feed line connecting the pump and the vessel to be evacuated, so that all the air passes through the trap before entering the pump. A simple trap consists of a glass tube inside which is a detachable silica trough filled with phosphorus pentoxide. This is in the form of a powder, and is obtained when phosphorus is burned in oxygen. It has a great affinity for water and is, therefore, ideal for the job.

The tube to be pumped is joined to the exhaust manifold, and to this manifold are connected the bottles of gas. Their outlets are controlled by ground-glass stop-cocks, as are all the other pump connections, so that the operator controls them at will.

We have described the type of pump most commonly used for neon sign manufacture, and can now pass on to the manner in which this pump is operated. Before doing so, however, a few notes of other types of pumps will be helpful.

The two-stage rotary oil pump is not the only type used for producing a vacuum, but for general commercial work, where an extremely high final vacuum is not absolutely necessary, it is most efficient. High pumping speed is essential to the development of a good neon tube, and this may be facilitated somewhat by the use of a secondary pump in series with the oil pump. The secondary pump can be of either the mercury or oil diffusion type, which rely upon mercury or oil vapour respectively. The mercury or oil is heated and the vapour thus given off creates a vacuum as it descends to the bottom of the pump. Diffusion pumps are very quick in operation and produce

under favourable conditions a vacuum of the order of $10^{-7}$ mm. of mercury. The primary or " backing " pump need not be a two-stage oil pump but can be a single-stage machine, and its object is to maintain the diffusion pump under a more or less continual vacuum.

The successful operation of mercury or oil diffusion pumps—particularly of the former—demands great care and attention, and the maintenance of the correct temperature of operation and the replenishment of the cooling medium which the mercury pump requires are points which tend to make the two-stage rotary oil pump appeal to the general neon tube maker.

An oil diffusion pump recently put on the market is an extremely efficient job, and it has few of the disadvantages possessed by the mercury pump. A higher degree of skill is, however, necessary for its operation, and if this is not forthcoming its advantages can readily be nullified. To return to the oil pump. The pump has two external connections, one through which the air is drawn from the vessel under treatment, and the other through which the air so drawn is expelled into the atmosphere. The first of these we will call the inlet.

The inlet pipe is connected to a glass bulb termed an " oil trap," having two cock-controlled branch pipes. The first of these is the inlet tap, which we will call I.T., and the other we will call O.T. Now if we seal our vessel to the inlet tube and evacuate it, and then seal it off, we find that during the evacuation process the air has been drawn from the inside of the pump and that the action of sealing off has sealed this vacuum. The only other connection to the pump is through the oil-sealed valve, and this will be found not sufficiently strong to resist the comparatively high external pressure for any length of time, with the result that the oil will gradually soak through into the inside of the pump in an effort to equalise the pressure. Thus the whole machine becomes filled, and before any further work can be done it has to be completely dismantled and cleaned.

It is to prevent this inflowing of oil that the tap O.T. is provided, the purpose of this being to allow air to enter the pump system after the sealing off.

Between the tap I.T. and the sealing-on point is placed first the dehydrating trap and then a branch tube, and to this tube is connected the bottles of gas, their outlets being controlled by ground stop-cocks. We will term this branch the "gas manifold." If we seal a length of tube to the exhaust manifold, turn off all the gas taps, and turn on the pump tap (*Note*—see that the tap O.T. is closed to the atmosphere), the whole system will be evacuated, including the gas manifold. Now if we turn off the pump tap I.T., the vacuum will be maintained in the manifold, with the result that, if a gas tap be turned on, the manifold and the tube will be filled with gas.

A manometer or pressure gauge is connected in the pump circuit. This gauge is usually of the mercury "U" type, and is used to enable the operator to control the gas pressure.

We have stated that the gas bottles are connected to the manifold by means of a tap. Actually there are two taps, and these are placed so that there is about 3 inches of tubing between them. The purpose of this is to enable the operator to admit small quantities of gas at a time. He first opens the tap nearest the bottle and thus allows the short connecting piece of tubing to fill. This tap is then closed, and when the front one is opened the only gas available is that in the tube between the two taps.

The object of the pumping system is not only the production of a hard vacuum but also the elimination of the gases from the glass and the electrodes. This gas is eliminated from the materials by the application of heat, and the heat is applied to the electrodes by bombardment and to the glass by baking.

When the glass and metal are heated to such a point that they throw off the gases contained in them, the pump must be able to draw off these gases at a sufficient rate to prevent their reabsorption into the materials as they

cool. It is evident, therefore, that all parts of the pump and manifold must be maintained at the highest standard of cleanliness, and that the entrance of all forms of foreign matter be prevented.

The bombarding machine is a transformer built specially for the job. The voltage across the secondary may be anything up to 20,000, and the capacity up to about 10 K.V.A. The output from this machine is controlled by means of an adjustable choke and voltage regulator, so that the operator may at will vary the current and pressure at which he bombards the electrodes.

To exhaust and fill a neon tube, first seal it on to the manifold, and connect the high tension terminals of the bombarding system to the electrodes. Go all round the pump and see that everything is in order before starting up, and make sure that the tap O.T. is turned off or closed.

Start up the pump, open tap I.T., and flash the current across by a quick movement of the switch. When the tube lights, shut I.T., switch on the current again, and adjust the transformer until the meter in the secondary circuit is reading 100 or 120 milliamps. Leave the tube alight for a few seconds and then cut in the pump and switch off the current.

Whilst the tube is being evacuated, periodically flash the current until this action produces no resultant glow in the tube. It is now evacuated, but the heat generated during the process has liberated gases from the glass and metal, and these must be pumped out. Cut out the pump, allow fresh air to enter (through a branch from the exhaust manifold), and repeat the pumping process after having increased the current to about 150 milliamps.

This admission of fresh air and re-pumping should be repeated three to four times, when the glass and electrode metal will be completed gas free and the tube can be thoroughly evacuated. This will be apparent when no glow results from the throwing of the switch.

When the tube is evacuated, and whilst it is still warm, close the pump tap and allow the tube to fill with about

10 mm. of neon. Seal off, and the tube is ready for ageing.

The gas pressure will be decided by the diameter of the tube and the gas used, but for most purposes it will be found that a pressure of from 9 to 11 mm. is adequate.

The number of available colours for neon signs are more or less limited to three, namely, RED, BLUE and GREEN. Red, or, more correctly, deep orange or flame colour, is obtained by filling the tube with pure NEON ; blue, by filling with a mixture having ARGON as its chief constituent, and in addition to the gas a small amount of mercury is added to the tube. Green is produced by filling a tube of light canary or uranium glass with a mixture similar to that used for blue. Note that the glass used for red and blue is clear. Various shades of the above three colours can be produced by the use of coloured glass tubing.

If a white glass tube be filled with HELIUM the resulting glow will be pinky-white. This colour is not very favourable, as it is not brilliant, and in addition it requires considerably more voltage to produce a steady glow. The voltage required to strike 40 feet of helium-filled tubing will be about 20,000, whilst that for neon-filled tubing will be only 10,000.

A rather bluish-white tube can be made by filling opal glass with the mixture used for blue and green, and whilst mercury is used for these latter colours, this may be eliminated under certain conditions if white is the object. It is a very difficult job to produce a pure white—and at the same time consistent—tube, and it is safe to say that this has not yet been done, at least on a commercial basis by the trade generally.

We have already made some observations on " rippling " neon tubes, and the ripple can be studied whilst a tube is being pumped. During the first evacuation a lot of moisture is drawn out of the tube, and the effect of this moisture on the discharge is to cause it to ripple. This is noticed almost exclusively with blue and green

tubes, and can be put down to moisture in the mercury as the chief source of trouble. By heating the mercury before putting it on the tube, the rippling can be almost eliminated, although one enterprising company has exploited this " defect " to some advantage.

We have seen that the elimination of moisture from the neon tube is the largest item with which the pumper has to contend. The speed of the pumps should be as high as possible, and the apparatus between the pump and the tube must be so arranged that the pumps are allowed to develop their full speed. So we can say that if the manifold is inefficient the degree of evacuation will be inefficient.

With regard to the construction of the manifold, this should be entirely of glass. Rubber connections should not be used, as the rubber gives off impurities which add to the load on the pump. The diameter of the manifold should be not less than 16/19 mm., and, in fact, the whole of the glass-work forming the pumping system (this glass work is termed the " Canalisation ") should be of large diameter. Small diameter tubes increase the resistance, and hence lower the speed of the pumps, with the result that the impurities from the tube are not drawn out with the desired speed. The diameter of the stop-cocks should be in agreement with the rest of the canalisation, and in passing, it is interesting to note that in a large number of cases, although the manifold is of a large diameter, the stop-cock bore diameters are perhaps only half of this, with the result that the pumping speed receives a serious set-back.

Whilst on the subject of stop-cocks, these may at times be prolific breeders of impurities, due to the impure vapours given off by improper grease. Proper vacuum grease should always be used, applied sparingly to the top of the ground surface. There is no necessity to anoint the whole of the cock, as if this is done it will be found to trickle out through the bore into the connecting tubes.

It will be found that after a time the water vapour

liberated from the neon tube and drawn through the manifold by the pump, has, due to the coldness of the manifold, condensed around its walls. Heating of the manifold whilst the pump is running may result in the water being drawn off, but if this cannot be done, or if it is unsuccessful, the manifold should be replaced. This replacement should, in any case, be effected after the manifold has been in use for any length of time, as small particles of mercury may be lodged in the corners, and later sucked into the pump, with disastrous results.

The dehydrating trap, the purpose of which is to absorb all the moisture passing from the neon tube, must be replaced as often as is necessary to prevent saturation of the phosphorus pentoxide. If this were to occur, the moisture would be sucked straight through and the pump would act as a condenser and water would collect.

If the degree of vacuum obtained appears to drop, remove the lid of the pump box and observe the oil. When the pump is evacuating a vessel, there will appear around the top of the oil valve a continuous stream of frothy bubbles, and as the vacuum improves there will be a gradual dropping off of the number of bubbles appearing. When completely evacuated, there should be no bubbles, and an " empty " sound heard. If observation shows that this is not the case, then there is a leak somewhere in the system, which can be traced by cutting out the separate parts individually, and so localising the fault.

Leaks can be cured or prevented by examining and regreasing all stop-cocks, and by paying attention to all joints, etc.

To empty and replace the oil, first rotate the pump with the inlet tube open to the outer air. Remove sump plug and empty out the oil, after which thoroughly clean the inside of the box with rags, *not* cotton waste.

Replace the plug and pour in about a pint of oil through the inlet tube, at the same time turning the pump by hand. This oil will thoroughly clean out the cylinders

and will be expelled through the exhaust tube, when it must be emptied out. Repeat this operation until the oil so expelled is clean, after which the proper filling may be done. Fill the pump box until the actual unit is under the level, and then pour a final pint or smaller quantity through the inlet opening, turning as before. When this latter oil has been expelled in the usual manner into the main supply, the pump is ready for use. The oil used should be a proper vacuum-pump oil, as this is specially blended for vacuum use. Ordinary oil must not be used.

## § 51. *AGEING OF TUBES*

After the tubes have been filled, they should be " run " for a short time before being dispatched to the site. This running-in process is known as " ageing," and it allows the tube to settle down to its proper working colour and conditions.

In some cases where speed of production—as, for instance, with repairs—is very necessary, the tube may be sent straight from the pumping bench to the job, but wherever possible it should be given a preliminary run. Ageing is best carried out by running the tubes very low, so that a slight flicker is present. Ageing the tubes by running them brightly is not very satisfactory, particularly immediately after pumping, as any impurities which have not been eliminated will work out during the ageing and possibly cause the tube to go off colour.

An excellent method is to connect about two or three times the normal footage to one transformer and allow it to run, say, all night. In the morning it will be found that the colour of the tubes is excellent, and this colour will be maintained when the tubes are connected on the job. An alternative method of ageing is to run the tubes for a short period at their normal operating characteristic, and then for a short time increase the current passing through them to about twice the normal figure, after which they may be run for a longer period in the manner described above.

Different manufacturers naturally employ different methods of ageing, but the foregoing will be found generally suitable.

Ageing is more necessary with blue and green tubes than with red tubes. With blue and green, a small spot of mercury is added during the processing, this mercury being contained in a small bulb blown onto the exhausting stem. After pumping and filling, the tube should be sealed off above the mercury container, and the tube aged-in before the mercury is tipped in. After a suitable period of ageing, determined by the colour of the tube, the mercury is tipped in and the bulb sealed off.

When aged, during which any slight tendency to disturbance of the tubes colour caused by the presence of minute impurities has been eliminated, and the tubes have settled down to their normal characteristics, it is advisable to allow them to run for a short time connected to the transformers which will operate them whilst on the job. This serves the dual purpose of testing the transformers, and also checking their capability to operate the tubes for which they were designed.

## § 52. *TRANSFORMERS*

It is to Faraday that we owe the transformer, a description of which will perhaps be the best introduction.

In the early days of discharge tube experiments Faraday was well to the fore, and with a number of other experimenters deplored the absence of any means whereby a high voltage could be maintained for any length of time. During the course of his experiments he found that by winding two separate coils of wire around a bundle of wires formed into a ring, and passing a current of electricity through one of the coils, a current of electricity was caused to flow in the other coil at the make-and-break of the circuit between the first coil and the battery. Continuing these experiments, he found that the relative number of turns of wire forming each coil governed the

magnitude of the currents flowing, and that provided he had a sufficient number of turns he could cause an almost unlimited voltage in one coil from a small voltage in the other. This action is termed "induction," and the current passing in the first or "primary" coil is said to "induce" a current in the other or "secondary" coil.

This, then, was the basis of the modern transformer. After the first experiments, the problem arose as to the method to adopt to continually make-and-break the primary circuit, as it is only at these two points that the secondary current is induced. This point was solved by introducing a "trembler" or electro-magnetic relay which under the action of the battery—on a similar principle to that adopted for the modern electric bell—caused alternate make-and-break of the circuit. Thus the high voltage secondary current was intermittent and the degree of intermission was dependent upon the speed of the trembler.

For neon signs we use what are known as static transformers. These operate on alternating current without the necessity of any mechanical means of making and breaking the circuit.

Current as supplied from the power stations is either direct or alternating. In the first case, the characteristic "curve" is a straight line, and the voltage remains constant with definite positive and negative poles. This type of current is also known as a continuous current, which term is self-explanatory. Alternating current, on the other hand, is as the term implies, not continuous. Starting at a value of 0 the current rises to a maximum positive value, after which it decreases to 0 again and then to a maximum negative value, then back to 0. This represents one complete cycle, and the curve followed is known as a "sine" curve. The frequency of the current is the number of cycles passed through per second. Normal A.C. supply is of 50-cycle frequency.

Thus we see that where an alternating current supply is available, the question of making and breaking the

circuit is automatically solved. This takes place every time the curve cuts the base line, or 100 times per second with a 50-cycle supply.

Neon sign transformers may be either "shell" or "core" type. These are shown in Figs. 15 and 16.

The "iron circuit" is made of good quality soft iron built up of laminations each about 15/1000ths of an inch thick. The reason for laminating the iron is the elimination of "eddy" currents, or circulating currents set up by the flowing of the main current. Unless these eddy currents are prevented from forming, a percentage of the power of the transformer is lost.

The laminations, provided they are insulated from each other, provide a sufficient quantity of iron for the purpose of transformation, and are at the same time too thin to allow the generation of eddies. The insulation of the laminations is usually effected either by painting or by spacing them apart with thin sheets of prepared paper, and care must be taken to see that the edges of the sheets or laminations are smooth, or the paper will be cut and the insulation lost.

The coils are wound apart from the core, and when ready are slipped into position.

Neglecting the losses in a transformer, if we wind a machine having one turn on the primary and twenty on the secondary, and pass an alternating current of 1 volt through the primary, there will be induced in each coil or turn of the secondary a current of 1 volt, so that the total secondary E.M.F. will be 20 volts.

Thus in the ideal machine the transformation ratio, or the ratio between the primary and secondary E.M.F., is given by :

$$\text{Transformation ratio} = \frac{\text{Primary turns}}{\text{Secondary turns}}$$

In a similar way we can say that the ratio between the amperes in the primary and secondary windings has a value equal to the transformation ratio. From this

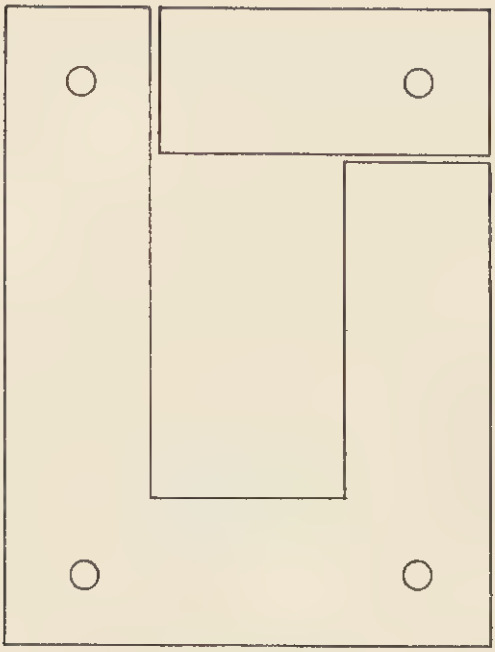


FIG. 15.

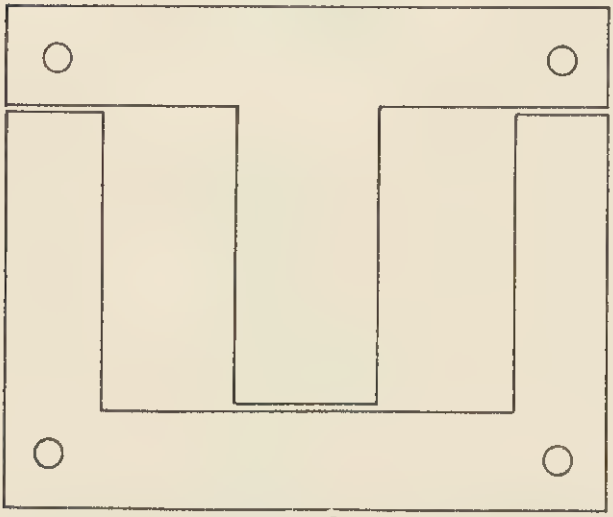


FIG. 16.

Laminations for transformers suitable for Neon Signs. The upper figure shows a Core type, and the lower figure a Shell type.

follows the fact that the product of the primary amperes and volts is equal to that of the secondary amperes and volts—in other words, the input watts equal the output watts.

Therefore, for a transformer to operate a neon sign at 10,000 volts from a mains voltage of 250, the ratio between the primary and secondary turns will be :

$$\frac{250}{10{,}000} = \cdot 025$$

or we can say that a transformer of ratio 40 to 1 step-up will do the trick.

The current required at the secondary will be about 30 m/a, in which case the primary current will be :

$$40 \times 30 = 1200 \text{ m/a, or } 1 \cdot 2 \text{ amps.}$$

When designing a transformer for a specific job, the size of the iron core together with the size and number of the primary and secondary turns will depend upon the required output.

Transformer losses arise from a variety of sources. First are the iron losses, these depending upon the quality and disposition of the iron. We then have a loss through magnetising current, and there are further losses such as copper losses, in the actual windings. These losses are guessed approximately for a new design, and are checked up when the design is complete. If the guesses were wrong, then the design can be modified in the light of the new knowledge.

During the operation of the transformer a certain amount of the electrical energy is dissipated in the generation of heat, this accounting for a further loss.

The design of neon transformers is somewhat different from that of ordinary machines, due to the peculiar characteristics of the neon tube. We have seen that whereas a very high voltage is required to start the discharge, a smaller voltage will maintain it. Thus the striking voltage of a circuit may be 10,000, whilst the voltage under working

conditions will be about 7000, which is the voltage for which the tube may be considered to have been designed. If the transformer were to continue to deliver 10,000 volts after striking, the current would be considerable, and the transformer would burn up. It is necessary, therefore, to incorporate some means whereby the current is automatically limited. This is usually carried out by means of a magnetic leak, which is adjustable and so allows the "reactance" to be varied. The method of varying the reactance differs with individual transformers, but it consists essentially in varying the intensity of the magnetic circuit.

Neon tubes have an inherent falling volt-ampere characteristic, and to stabilise the operation of the tubes the above method of providing transformers having a high internal reactance is generally employed. This is very efficient in that any increase in current causes a simultaneous drop in voltage, but it has one disadvantage in that the power factor of such transformers is very poor, namely, about 50 per cent.

This does not greatly affect the consumer unless he is paying for his supply in accordance with a two-part tariff. Such a tariff is composed of one component based on the connected load, and the other component based on the power actually consumed. Now a low power factor means that the power company must connect a greater load than that which will be consumed, hence one part of the tariff is greater than it would be were the transformers of a higher power factor.

Similarly, the fact that the supply company has to connect a greater load, means that in the case of a D.C. job where a rotary converter is necessary—the capacity of the converter will have to be greater, and will in consequence cost more.

Power factor correction is, however, a simple matter, and is carried out by connecting a condenser across the primary or mains supply. The value of this condenser varies according to the mains voltage, the frequency of

the supply and the correction which is required. The power companies usually require correction to ·8 lagging, and this means that a condenser of about 10 to 15 mfd. will suffice with a 230-volt 50-cycle supply, for a transformer of about 10,000 volts open circuit at 25 m/a, provided that it is reasonably efficient.

Neon transformers for outside use are contained in metal cases and have their windings sealed in with a bitumen compound. Some transformers have their windings immersed in oil, but this is rather expensive and calls for a special grade of oil if efficiency is to be secured, and has the additional disadvantage that transformers so cooled are more liable to fire than those whose windings are bitumen or compound sealed. Air-cooled transformers are used for inside signs and for box signs, but should not be used for general outside use.

The footage which can be operated from a given transformer involves considerations of gas pressure, type of gas and diameter of tube. In general, a 10,000 volt 25 m/a transformer will operate about 40 feet of red tubing of 14/15 mm. diameter. With larger tubes a greater current may be passed, and the voltage then drops, with the result that a 10,000 volt 50 m/a transformer will operate a longer length of 20 mm. tubing than that of 15 mm. operated by a 10,000 volt 25 m/a transformer. It is impossible to give any figures which may be used without reference, and it is advisable to estimate on the liberal side and check up when the tubes are made.

## § 53. *CONDENSERS*

Condensers for power factor correction are connected in parallel with the supply to the transformers, and it should be noted that where 20 mfd. capacity is required and only two 10 mfd. condensers are available, the two condensers should be connected in parallel and not in series with each other.

It is preferable to install the condensers at a point close

to the transformers, and not to bank a large number together on the mains side of the distribution board, although this method may be the cheaper.

There is no danger of receiving a shock through the condenser discharging when the sign is switched off, as it discharges itself through the primary winding of the transformer unless there is a broken lead somewhere.

It is recommended that a " grid-leak " be permanently connected across the condenser terminals, so that an immediate discharge takes place on the breaking of the circuit.

## § 54. *ELECTRODES*

Of the tubing itself, the electrodes are perhaps the most important component, since it is upon their efficiency that the performance and life of the tube depends.

It has been pointed out that the light given by a tube consists of two parts, namely, that immediately around the electrodes, and the main light known as the " positive column." The latter feature is the one in which the sign-maker is chiefly interested, but the former is a factor which, from the manufacturing point of view, is the most important.

Neon tubes, due to the high voltage required for their operation, employ alternating current, with the result that the electrodes are continually changing their character. Thus with a 50-cycle current supply, the electrodes change from cathode (negative) to anode (positive), and *vice versa*, 100 times per second. It is the electrode's characteristic when it is acting as the cathode with which we are interested, and it is at this time that a poor electrode will be manifest.

For simplicity of explanation we will consider a tube operated by means of a direct current, so that there is a permanent anode and a permanent cathode. Now before the current is switched on, the tube—in so far as the gas is concerned—is stable or is in a balanced state ; that is, each gas atom is surrounded by its normal number of

electrons. When the current is switched on, a stream of electrons is emitted from the cathode, and provided that the energy level through which these electrons have been raised is lower than a certain critical value depending upon the gas, the electrons will travel through the tube and amongst the gas atoms without causing any inelastic collisions. When, however, the voltage is increased to such a point that ionisation takes place, a glow is produced and a number of gas atoms are unbalanced through the ejection of one or more of the electrons. These atoms are now of positive polarity, and obeying the magnetic law that unlike poles attract, they travel to the cathode, on which they impinge with a velocity depending upon the gas pressure. This bombardment of the cathode continues throughout the life of the tube, and the bombarding ions attract after the collision sufficient electrons to allow them to resume their normal physical state.

The continual bombardment of the cathode, or in the case of the neon tube, the two electrodes, gives rise to what is known as " cathodic sputtering," which is more violent with low pressures than with high pressures. Cathodic sputtering is the ejection of minute particles of the cathode material by ionic bombardment, and, generally speaking, the higher the cathode drop in potential, the greater or more violent will be the sputtering. The ejected metal is thrown off at very high speed, and becomes attached in the form of a film to the glass tube immediately surrounding the electrode—or, more correctly, the cathode—and as the metal attaches itself to the glass, it traps atoms of the gas. This performance continues during the whole operation of the tube, with the result that after a time a quite appreciable film is formed and also a quite appreciable percentage of the gas is trapped and so removed from its normal function, or, in other words, the pressure of gas in the tube is reduced.

The formation of the metallic film is not so important as is the trapping of the gas, for the following reason. If the gas in the tube were at atmospheric pressure, a very

high voltage would be required to start a discharge, and such discharge would not take the form of a glow but the undesirable form of a spark. The pressure is, therefore, much lower than atmospheric, which means that a much smaller quantity of gas is present in the tube and, therefore, the electrons and ions can attain a greater speed before collisions. Thus, as the pressure of the gas is reduced below that normally employed, the gas atoms are very far apart, and consequently the ions are allowed to attain a still higher speed. The velocity of both the electrons and ions is inversely proportional to the gas pressure, with the result that the reduction in pressure caused through sputtering causes subsequent sputtering to take place at a greater speed, owing to the greater speed of the bombarding ions. After a time the gas pressure will have been reduced to such a low value that only a few gas atoms are present, and therefore the chances of ionisation are reduced. A higher voltage would then be necessary to maintain the discharge, and unless the transformer size is increased the tube will start flickering. Increasing the transformer size, however, is not the correct solution, because the gas pressure is still low, and consequently in time the tube will " harden," *i.e.* most of the gas will have been trapped and the application of a higher voltage will cause the tube to break down.

We have seen that the cathode fall is an essential feature of an electrode, and that upon this value depends to a large extent the resistance of the electrode to sputtering. The lower the cathode fall, the longer will be the life of the tube. The table at top of next page shows the cathode fall for a number of commonly used materials in the various gases.

From the table it would seem that potassium or sodium electrodes are the most desirable, but manufacturing considerations render them useless for general application. In addition, the colour distortion produced by the use of sodium is greater than would be tolerated for sign work.

VOLTAGE DROP

| Metal. | Neon. | Helium. | Argon. |
|---|---|---|---|
| Aluminium . | 140 | 150 | 145 |
| Copper . . | 210 | 170 | 150 |
| Iron . . . | 156 | 162 | 166 |
| Magnesium . | 122 | 126 | 150 |
| Potassium . . | 68 | 68 | 71 |
| Sodium . . | 72 | 74 | 73 |

Reading down the list, we come to magnesium as the next apparently desirable material, closely followed by aluminium. These two metals have a low cathode drop, but it is a very difficult matter to produce magnesium or aluminium of sufficient purity for electrode manufacture. In addition, the melting-point of each of these metals is round about 650 degrees C., which is lower than the red-heat temperature of iron, so that very careful temperature control is necessary during the manufacture, and the bombarding process is therefore complicated.

We are now left with copper and iron, and opinion is more or less evenly divided regarding the suitability of these two metals. In some firms copper is used almost exclusively, whilst the same position obtains in other firms with iron. So far as the cathode drop is concerned, iron would appear to be the better, but the manufacturing processes through which it is necessary to pass the iron to secure a material of maximum purity are very involved and expensive. Copper, on the other hand, although it has a high cathode drop, can readily be produced in large quantities of more or less absolute purity. This brings us to the question of purity of the metal, and its effect on the performance of the tube both during processing and in after-life.

The material of the electrode should be electrolytically pure, otherwise there will be erupted during the life of the tube harmful gases which will interfere with the degree and consistency of the illumination, and shorten the useful life by impairing the vacuum. These gases may be divided into surface gases and imbedded gases. The former are capable of elimination by cleaning the electrode before it is assembled. If hand-made electrodes are used, the grease marks of the operators can be removed by washing with carbon tetrachloride, or acetone. The gases stored in the material are a function of the manufacture. Some of these can be eliminated during the bombardment process, but this process, compared with that being conducted during the life of the tube, is very short and slow. If the metal is treated properly before being incorporated as an electrode, there will be few troubles in after-life. One of the methods used to ensure pure metal is that of melting in a vacuum furnace, through which hydrogen is caused to pass. This prevents oxidation of the material and the separating-out of oxidising agents.

The effects of bombarding are similar to melting the metal in a vacuum furnace, but the respective degrees of heat are very different, and whilst the former method assures the elimination of the near-surface impurities, complete vacuum melting is required for thorough cleaning.

Provided the pumping under bombardment is carried out for a sufficiently long period, the electrode material may be of the lowest quality, but for speed in manufacture, and long and trouble-free life, the purer the original metal the cheaper the costs.

The electrode must be constructed so that it is structurally rigid. The connection of the lead-in wire to the electrode "shell" should be good electrically, and the sealing-in to the foot should be of a generous nature.

Most electrode elements take the form of a cylinder of metal the thickness of which varies from ·1 to ·2 mm. for

sheet-iron spot-welded along the seam, whilst copper electrodes are generally drawn. Iron mesh is sometimes used, but there would appear to be no definite advantage over sheet.

In addition to sodium and potassium mentioned in the table, three other alkali metals, Barium, Cæsium and Rubidium warrant mention. These metals have a low cathode drop, but considerations of expense and mechanical suitability render them unfit for general use. A compromise can, however, be effected by coating the surface of, say, an iron or copper electrode with one of the above alkali metals. These coated electrodes are very efficient, provided that precautions are taken during the bombardment process against driving off the coating. Coated electrodes are useless for tubes where mercury is used, as the mercury attacks the coating.

The comparative testing of electrodes is necessarily a tedious process, particularly as the life of some electrodes is as high as 20,000 hours. The testing may, however, be accelerated by the use of tubes filled with gas at a low pressure and run continuously at a definite characteristic. The electrodes for test should be sealed into a tube of about 15 mm. diameter, so that the two electrodes are directly opposed to each other, with a space between their respective lips of 9 to 12 inches. The tube should be filled with a pressure of 5 mm. and allowed to operate at a current of 35 m/a. This greatly speeds up the life or the rate of living of the tube, and allows comparative data to be secured in a comparatively short time.

## § 55. *LIFE OF TUBES*

First, it will be well to define the fair average life of a neon tube.

Three thousand hours of lighting life is an economic one, although some tubes do less and others considerably more. Three thousand hours of lighting life is equal to about two years of average sign-lighting hours. This is

based on a sign being lit one hour after sunset and operating to 11 p.m.

If the average time of switching off is earlier, then the 3000 hours will, of course, cover more than two years.

There is a variety of factors which can contribute to the shortening of the life of a tube. Some of these are manufacturing faults, hereinafter enumerated. Others are installation faults. Of the faults due to manufacture, the first that can easily bring failure is fracture of the bent tube due to strain left in the glass when worked into shape by the blower. This strain is always more or less present in glass, and its degree depends on the skill of the glass-blower in annealing it after working the tube.

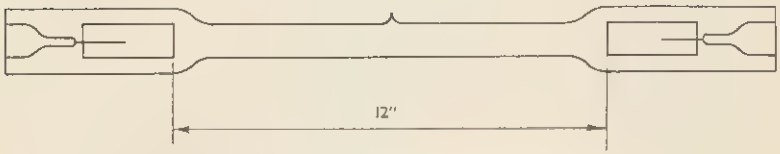



FIG. 17.

A Life Test Tube suitable for comparison testing of electrodes. The sealing pip should be exactly in the centre as shown.

Next is the lack of thoroughness in cleaning the tube and electrodes during pumping and filling.

The last and most vital is the pressure of the filling gas. This pressure affects the tube life in a very direct manner, namely, its hours of lighting life will be proportional to the square of the pressure.

In this country, from 4 to 10 mm. of pressure of neon in the tube has been customary. The pressure is gauged by a mercury manometer.

In the U.S.A. it is becoming the practice to fill at anything from 12 to 25 mm. Let us for a moment examine what the "square-law" life means.

Assume a tube A is filled at 6 mm. pressure of neon, and another tube B at 12 mm. The square of the tube A is 36 (6 mm.×6). The square of tube B is 144 (12 mm.×

12). This means that tube B has four times the expectation of life of A. It follows that a tube filled at 18 mm. pressure would have a life nine times that of a 6 mm. pressure tube. This being so, it occurs to the layman, " Why not fill every tube of any size at the highest pressure at which it would operate ? " The answer is that increased gas pressure, whilst giving longer life, also offers greater resistance to the passage of the electric current through it, and it therefore needs a higher voltage to energise or light a given length. This means that more " standard " transformers per sign would be required, with a consequent increase in prime costs.

Fierce competition among tube manufacturers compels many of them to keep the number of transformers down to the lowest possible to operate the sign, and so the filling pressure is also kept down to a point only just sufficient to ensure the tubes lasting out safely the guaranteed period. Renewal of tubes becomes therefore the responsibility of the owner.

If, however, in the first instance a few more transformers had been used and the tube pressure increased, it is conceivable that a life of ten years, or even 15,000 lighting hours, could easily have been obtained.

Moral buy neon on quality first, and buy it from those whose technical knowledge of the job is such that they endeavour to deliver tubes where the cost of life efficiency is weighed against initial cost. This will ultimately be the cheaper sign.

Of course, there is an upper limit of pressure from which it is not practicable to increase, as the voltage per foot becomes excessive and the light a narrow core of glowing gas, known as " Haywire " light in the U.S.A.

The installation faults are mainly brought about by adverse climatic conditions, such as rain, high winds, etc. ; poor insulation of cables ; neglect to ensure that rain does not cause a short circuit ; letters made of inferior wood that swells with moisture and shrinks when dry, and so breaks the glass ; expansion of iron rails or frames which

are wedged tightly between stone or brick piers, and being unable to expand freely laterally, take up a bowed shape when expanded, and finally bend beyond the very limited elasticity of the tubes ; and binding tubes too tightly onto the supporting clips or posts so that they are strained and finally crack and give way.

Another frequent cause of failure is brought about by too small a clearance around electrode holes in panel signs. This gives rise to two classes of trouble : First, there is a great likelihood of rain bridging the gap from the panel to the electrode case, causing the high tension on the electrode itself to strike to earth and puncture the glass wall of the casing.

Secondly, it may mean that the electrode case is bearing all the time against the edge of the hole in the panel or letter, and is being continually strained. A slight movement of the panel or tubing through wind, damp, or heat may complete the strain needed to fracture the tube.

Again, faulty installation at the transformer end may bring about failure of the sign although it may not necessarily harm the tubes.

The cables, both high and low tension, particularly the former cause trouble unless proper precautions are taken. If they are not dipped downwards and up into the transformer, so that rain cannot flow along them into the transformer, a short circuit and possibly a burning-out may result.

The high tension cable ends must be treated in accordance with the instructions set out in a previous chapter. Series wires must be firmly fixed to electrode caps in order that they may not develop an intermittent contact which would first of all make the sign flicker and finally, if prolonged sufficiently, will cause a heating-up of the cap by the miniature spark developed at the moment of interruption of the circuit. This would unduly heat the glass electrode case inside the electrode cap or terminal, and cause the glass to crack and put the tubes out of action. Even if this small spark did not damage the glass, it would

cause the series wire to be burned away, and bring about a disconnection of the circuit.

All these possible faults, although not directly tube faults, affect the continuity of the lighting hours of the sign, and consequently have a direct bearing on their longevity.

In the past, manufacturers have given guarantees for sign life of 1500 to 5000 hours, and in other cases of 6 or 12 months, but generally their guarantee was useless and markedly unfair to themselves and in some cases to the consumer.

It led to many disputes between the consumer and the manufacturer or supplier, and caused neon sign "guarantees" to be treated with suspicion.

It is conceivable that a sign user might operate his sign 24 hours a day (8760 burning hours in one year). Obviously it would be unjust to demand replacement from the maker under his twelve months' guarantee. Yet how could the manufacturer dispute the claim—however unjust—if he is led to believe that the sign has been running for less than 3000 burning hours.

On the other hand, a consumer might light his sign from only one hour after sunset to 9 p.m. This would mean a little more than 500 hours a year, and after, say, three years he would still not have exhausted the guarantee period of the tube life, and yet it would be difficult for him to substantiate his claim against the maker. There is only one method that is just to both the buyer and seller, and although not in general use it will undoubtedly be common practice in a few years' time.

It is to install a separate special consumer's Watt-hour Electricity Meter, of the type fitted by the electric supply companies, and recording the current used by the sign. The number of units registered, divided by the sign consumption per hour—specified in the tender or contract—will give the hours of running. If the sign consumes 1·5 units per hour, and after 11 months the meter registered 4500 units, then the burning hours must have been 3000 (4500 ÷ 1·5—3000).

This would absolve the manufacturer from liability under his guarantee of 3000 hours to re-gas or replace sections of glassware and electrical components which may fail after this period, but of course still leave him responsible for all wood and metal constructional parts of the sign up to the twelve months.

It may seem unfair to suggest that the guarantee of electrical components should cease with the expiration of the guarantee of the glassware, but consideration will make it clear.

If the gas in the tubes is lessened by prolonged burning to such an extent that the tubes fail one after the other and need re-gassing, then this is almost equivalent to open-circuit conditions and is a great strain upon the transformers and high tension cables, which may rapidly break down, due to excessive voltage. The breakdown would certainly be no fault of the maker, but of the sign-owner trying to get more hours out of the sign than it is capable of giving. In fact it should be clearly set out in all neon contracts that *all* liability for the sign ceases with the expiration of the full period of burning hours, because the before-mentioned open-circuit conditions, quite apart from damage to the electrical components, may result in a fire being started which would most likely destroy or at least damage the non-electrical equipment of the sign.

It is likely ere long that special hour-reading devices, similar to the electric all-mains clocks, and independent of the sign current consumption, will be produced.

These should cost about 20s. to 25s. and will be self-starting and trouble-free, only operating when the sign is switched on.

# *GLOSSARY*

AGEING.—A process of neon tube manufacture which consists of running the tubes immediately after pumping to allow them to settle down to normal working conditions.

ALTERNATING CURRENT (A.C.).—Electric current which starts from zero, rises to a maximum positive value, falls back to zero, and then to a maximum negative value, again returning to zero, when the cycle is repeated. In other words, A.C. alternates between a maximum positive and maximum negative value.

AMPERE.—The electrical unit of current.

ANIMATOR.—An electrical device which permits signs to be "animated" by alternately cutting in and out the various circuits. Animators are usually of the mechanically driven type.

ANODE.—The positive electrode of a discharge tube, which, when the tube is alight, is covered with a glow in the form of a series of balls of coloured light. This phenomena is apparent only in the case of tubes working on direct current.

ARGON.—An element belonging to the gaseous group. This gas is used generally in conjunction with mercury, to produce blue, green and white tubes.

ATOM.—A body built up of positive and negative units of electricity, disposed as a central and positively charged nucleus surrounded by a group of negatively charged units or electrons.

BARIUM.—One of the alkali metals which is used to increase the emission of electrons from negatively charged bodies, such as neon tube electrodes, radio valve filaments, etc.

BALANCING TANK.—A tank or reservoir used in neon tube manufacture to balance the air supplied from the compressor and deliver it to the glass benders at a steady rate.

BELL GLASSES.—Glass insulators made up in the form of a bell and used to protect high tension cable ends and electrodes from electrical breakdown.

BITUMASTIC (Tape).—An insulating tape of the bitumen impregnated type used for insulating and protecting the ends of high tension cables.

BOOSTER (Electric).—An electrical device used to overcome the voltage drop at the end of a long line.

BOOSTER (Gas).—A device employed to increase the gas pressure in tube-manufacturing plants, when the normal mains pressure is insufficient.

BORO-SILICATE.—A grade of glass tube used in neon sign manufacture, which has a nature about half-way between the very hard silica glasses and soft soda glasses. This glass requires the addition of a slight amount of oxygen to the air supply to facilitate working.

BOSUN'S CHAIR.—A form of sling or cradle used when erecting signs and when cradles or ladders cannot be employed. The chair is slung from a window or other support.

CATHODE.—The negative electrode of a discharge tube, which is usually covered with a thin line of light of a reddish shade. The discharge commences from the cathode.

CATHODE (Cold).—The form of cathode used in the normal high tension neon tube, which employs no primary stimulus to the emission of electrons. As the name implies, the cold cathode operates at normal temperatures.

CATHODE (Hot).—The form of cathode used with low tension discharge tubes, in which the cathode is primarily heated either directly or indirectly, to promote the emission of electrons so that a greater current can be passed and a low striking voltage achieved.

CAVENDISH.—One of the early scientists and the original discoverer of Argon.

CLAUDE.—A Frenchman, and one of the first to employ neon tubes for commercial purposes.

CRADLES.—Platforms supported by means of ropes slung from "falls" erected on the top of a building, from which the sign-erectors work. The cradles can be moved at will, either up and down or along the building, and are used when ladders are unsuitable.

CROOKES.—A well-known scientist, and one of the main contributors to discharge tube research.

DIRECT CURRENT (D.C.).—Commonly known as continuous current, this, as the name implies, is electric current continuously positive or negative. There is no alternation from negative to positive, as with alternating current. Direct current, unlike alternating current, cannot be directly transformed to a higher potential, but must first be converted to A.C.

DISTRIBUTION BOARD.—An electrical device used to split up a single circuit into a number of sub-circuits, each having a separate pair of fuses. With neon signs, each transformer is fed from a separate sub-circuit.

ELECTRODES.—The " terminals " of a neon tube from which the discharge emanates. With high tension tubes the electrodes are alternately positive and negative or anode and cathode. The electrode usually consists of a cylinder of thin metal supported by two wires sealed into a glass pinch and connected to a metal cap or similar device on the outside of the tube, to which the cables are connected.

ELECTRON.—A negative unit of electricity.

EXHAUSTING.—A process in tube manufacture consisting of the extraction of the air from inside the tube prior to filling with gas.

FARADAY. A famous scientist who was responsible for a great deal of research work in connection with discharge tubes, and who gave us the first induction coil, the forerunner of the modern transformer.

" FEED-BACK." Interference generated in the primary coil of a transformer by impulses in the secondary coil. Feed-back interference contributes a good deal to the general interference between neon sign installations and radio sets.

FIREMAN'S SWITCH. An emergency switch which must be installed on the outside of buildings supporting neon signs, the purpose of which is to provide an immediate means of switching the sign off in the case of fire or other emergency. The switch must be so arranged that it is about nine feet from the ground and can be cut off by pushing the switch arm upwards.

FISHTAIL BURNER.—A burner used by neon tube benders for bending large curves. The burner is arranged in the form of a fish's tail, so that a long flame is produced.

FREQUENCY.—The rate at which alternating current passes through one complete cycle—that is, from zero to maximum positive, down through zero to maximum negative and back to zero. Generally, alternating current in England alternates at a frequency of 50 cycles per second.

GASSIOT.—A scientist engaged in discharge tube research, and who was responsible for the production of a high voltage cell by means of which he was able to substantiate many theoretical claims in connection with discharge phenomena.

GEISSLER.—A German scientist who did considerable valuable work in connection with discharge tubes. He founded the basis of the modern tube by sealing small platinum electrodes into his tubes. Geissler tubes are still used in schools for demonstration purposes.

GRID LEAK.—A protective resistance used in connection with neon signs as a means of discharging condensers installed for the correction of power factor.

HARMONICS. Impulses in the transformer circuit which tend to distort the current wave form from the truly sinusoidal, and so affect the power factor of the installation.

HAWKSBEE.—One of the earliest of the scientists interested in discharge tube phenomena who was responsible for a great deal of the initial work. The term "Mercurial Phosphorus" is due to Hawksbee.

"HAYWIRE."—An American term signifying that an installation is not functioning properly.

HELIUM.—An element belonging to the gaseous group, and used by tube manufacturers to produce a white light. Owing to its high heating value, this gas is also used during the manufacturing of the tube for bombarding the glass and electrodes.

HENRY.—The unit of inductance.

HITTORF. A scientist known for his work in connection with discharge tube research.

INDUCTANCE.—The property possessed by a coil or electromagnet which causes a retardation in the building up of the current when the circuit is made and a postponement of the falling-off when the circuit is broken.

INSULATING GLASS.—A glass insulator made up in the form of a bell or pipe, and used to protect the ends of high tension cable and electrodes.

Ion.—An electro-positive or electro-negative unit. Ions are formed in neon tubes in the first case by the ejection of an electron from the parent atom, and subsequently by collision with other atoms.

Krypton.—An element belonging to the gaseous group. This gas produces a lilac light, but on account of its high cost is not used to any great extent.

Laminations. Stampings of thin sheet iron used to build up the cores of transformers.

Lead Glass.—A glass belonging to the soft group and containing a certain amount of lead. This glass has a wide heat range, and is used for electrode feet mainly, but in some cases also for the whole sign. Special burners are required to work this glass.

Lumen.—The unit of luminosity used generally in conjunction with consumption as a basis for comparison of illuminants.

Magnetic Leak. A means of adjusting the reactance of neon sign transformers, by a small bundle of laminations which can be moved in relation to the transformer core.

Manifold Burner.—A burner used by neon tube benders and consisting of a number of jets concentrating to produce a continuous flame. This type of burner is used when bending tubes into long slow curves.

Mercury.—An element belonging to the metallic group and used by neon tube manufacturers in conjunction with various gas mixtures, to produce green, blue and white tubes.

Microfarad (mfd.).—One millionth of a farad, the practical unit of electrical capacity.

Milliammeter. An electrical measuring instrument used for measuring the current passing through neon tubes. This instrument is connected temporarily in series with the tubing whose characteristic it is required to read.

Milliampere.—From the neon tube manufacturers' point of view, this is the practical unit of current, and current instructions are given in the form of milliamps.

Moore.—A scientist responsible for the early commercial application of discharge tubes. Moore tubes were used in many outside installations, but owing to the fact that the gas used—carbon dioxide—cleans up, great success was not achieved. Moore was responsible for the replenishing device bearing his name.

MORGAN.—One of the early research scientists engaged in discharge tube work, and responsible for the establishment of a relation between the pressure inside a tube and the nature of the discharge.

MÜLLER.—A German scientist, known for his work in connection with discharge tube research.

NEON.—An element belonging to the gaseous group and used to a greater extent than any other gas in neon tube manufacture.

NOLLET (Abbé).—A French scientist, responsible for the production of what he termed an "electric egg," and who worked on lines parallel to those of Hawksbee.

PAKYDERM.—A proprietary brand of insulating varnish used in conjunction with bitumastic tape to protect the ends of high tension cables.

PHOTO-EXCITATION.—The excitation of a gas through the action of cosmic rays and other forms of radiation and radio-activity.

PICARD.—A French scientist, and one of the earliest in the discharge tube research field. He was probably responsible for the first published information on the subject, and it is on his work that that of Hawksbee was based.

PIPE GLASSES.—Glass insulators made up into the form of a pipe, and used to insulate and protect right-angle electrodes from electrical breakdown.

PLUCHER.—A German scientist, known for his work in connection with discharge tube phenomena.

PYREX.—A proprietary brand of extremely hard glass belonging to the silica group. This glass requires the use of oxygen to facilitate working.

RAMSEY (Sir William).—The scientist who, together with Lord Rayleigh, was responsible for the discovery of the gas Neon, and the development of the neon sign industry.

RAYLEIGH (Lord).—Co-scientist with Ramsey.

REIMER.—A tool used by glass benders for opening out holes in glass.

RHUMKORFF.—A scientist, known for his work in connection with discharge tube research and also for his work on induction coils.

RIBBON BURNER.—A burner used by neon tube benders where long slow curves are required. These burners provide a long, ribbon-like flame.

ROTARY CONVERTER.—An electric motor used to convert direct current to alternating current, so that it may be transformed to the necessary high voltage to operate the neon tubes.

RUBIDIUM.—An element belonging to the alkali metal group, and used as a means of promoting emission of electrons.

SERIES WIRING.—The wiring between sections of neon tubing.

SINUSOIDAL.—The perfect form of an alternating E.M.F. curve is sinusoidal—that is, it is of true sine form.

SODA GLASS.—The most commonly used form of glass for neon tube manufacture. This glass contains soda or borax, and is extremely easy to work and efficient in operation. Oxygen is not necessary to the working of soda glass.

SPRENGEL'S PUMP.—One of the earliest of the vacuum pumps, and developed by Sprengel.

SPUTTERING.—Sputtering, or cathodic sputtering, is the disintegration of the cathode caused by ionic bombardment, and is manifest in the form of a metallic film which is deposited on the glass surrounding the electrode, and which traps the particles of gas.

STRIATION.—Discs of light which can be made to appear in and travel along the tube under certain conditions. It is difficult to maintain this type of discharge, but it can generally be seen during the pumping operation.

STRIKING VOLTAGE.—The lowest voltage at which the tube will preserve a self-maintained discharge. In other words, the lowest voltage at which the tube will strike.

TEMPLATES.—Full-size paper drawings used by the glass benders, and to which they bend the tubes. These templates are drawn in reverse.

THERMAL STRAIN.—Strain induced in glass tubing by faulty heat treatment. Tubes which have been badly annealed and which are internally strained are liable to break when subjected to any change of temperature.

TRANSFORMER.—An electrical device used to transform the mains voltage to a value high enough to strike the tubes. Neon sign transformers usually transform the 200/250 mains voltage to a value of 10,000 or thereabouts.

Travers (Dr.).—A well-known scientist, and partly responsible for the work done in splitting up the atmosphere into its various components.

Uranium.—A very hard, malleable metal belonging to the radio-active group. This metal is sometimes combined to produce uranium glass of a greenish-yellow colour, which is used in the manufacture of green neon tubes.

Varley.—A scientist, known for his work in connection with discharge tube research.

Volt.—The unit of electrical pressure.

Watt.—The unit of electrical energy used in connection with current consumption.

Xenon. An element belonging to the gaseous group. Owing to the high cost of this gas it is not used to any great extent in neon sign manufacture, but when used alone produces a bright blue glow.

# *INDEX*


| TERM | PAGE |
|---|---|
| Ageing | 150 |
| Alternating Current (A.C.) | 27 |
| Ampere | 155 |
| Animator | 81 |
| Anode | 119, 158 |
| Argon | 2, 5, 6, 113, 119, 147 |
| Atom | 114 |
| Background Colours | 167 |
| Backing Materials | 31 |
| Balancing Tank | 136 |
| Barium | 163 |
| Bell Glasses | 26, 41, 42, 67 |
| Bitumastic (Tape) | 47 |
| Blast Burner | 134 |
| Bombarding | 146, 162 |
| Booster (Gas) | 136 |
| Border Tubes | 59 |
| Boro-Silicate | 137 |
| Bosun's Chair | 84 |
| Box Signs | 8, 50–54 |
| Bronze Clips | 37 |
| Bulb Signs | 30 |
| Calculating Footage | 100–102 |
| Canalisation | 148 |
| Cannon-Fire | 134 |
| Cathode | 119 |
| Cathode (Cold) | 128, 158 |
| Cathode (Hot) | 128 |
| Cavendish | 2 |
| Claude | 113 |
| Cleaning Tubes | 82–83 |
| Colour of Tubes | 17–20 |
| Condensers | 78, 108 |
| Compressor | 136 |
| Converter (Rotary) | 70–72, 156 |
| Core Type Transformer | 154 |
| Cost of Tubes | 109 |
| Cradles | 107 |
| Crookes | 111 |
| Cross-Cannon | 136 |
| Cross-Fires | 136 |
| Current Consumption | 28 |
| "Dead" Tubes | 87 |
| Diameter of Tubes | 17–20 |
| Direct Current (D.C.) | 72, 156 |
| Distribution Board | 69, 72, 86 87 |
| Double Outline Letters | 14 |
| Earth Return H.T. Wiring | 48 |
| Electricity Supply | 27 |
| Electricity Supply Requirements | 65 |
| Electrodes | 7, 43, 57, 158, 162–4 |
| Electron | 159 |
| Estimating | 103–109 |
| Exhausting | 146 |
| Facia Signs | 9 |
| Faraday | 151 |
| Faults | 87–90 |
| "Feed-Back" | 92 |
| Fireman's Switch | 25, 69 |
| Fishtail Burner | 135 |
| Flashers | 78, 81 |
| Fleming | 113 |
| Flickering | 87 |
| Fluoride Glass | 22 |
| Frequency | 73 |
| Fuses Blowing | 89 |
| Gassiot | 111 |
| Geissler | 2, 111 |
| Glass Clips | 37 |
| Glass Panel Signs | 55–58 |
| Grid-Leak | 158 |
| Guarantees | 167 |
| Harmonics | 78 |
| Hawksbee | 109 |
| "Haywire" | 165 |
| Helium | 4, 90, 92, 111, 113, 119, 147 |
| Henry | 92 |
| H.T. Cable Ends | 46 |
| H.T. Wiring | 40–41 |
| Hire-Purchase | 93 |

| TERM | PAGE |
|---|---|
| Hittorf | 111 |
| Hire-Maintenance | 96 |
| Inductance | 73, 152 |
| I.E.E. Regulations | 72 |
| Insulating Glass | 41 |
| Insurance | 58–59 |
| Interchangeable Letters | 14 |
| Ion | 116 |
| Krypton | 4, 113 |
| Lag | 74 |
| Lamination | 153 |
| Lead Glass | 137 |
| Length of Tubes | 63 |
| L.C.C. Regulations | 24–7, 72 |
| L.T. Wiring | 68–72 |
| Lumen | 130 |
| Magnetic Leak | 156 |
| Maintenance | 82–7 |
| Maintenance Materials | 82–3 |
| Manifold Burner | 134 |
| Manometer | 164 |
| Masonite | 12 |
| Mercury | 119 |
| Microfarad (mfd.) | 108, 157 |
| Milliammeter | 36 |
| Milliampere | 28 |
| Moore | 112–3 |
| Morgan | 110 |
| Muller | 111 |
| Municipal Requirements | 65 |
| Multi-Colour Tubes | 23 |
| Neon | 5, 113, 119 |
| Nollet (Abbé) | 110 |
| Opal Tubes | 22 |
| Outline Tubes | 59 |
| Pakyderm | 47 |
| Permissions | 24–27 |
| Photo-Excitation | 118 |
| Picard | 109 |
| Pipe Glasses | 41–2 |
| Plymax | 32 |
| Plucher | 111 |
| Positive Column Tubes | 127 |
| Potential | 49 |
| Power Factor | 72–6 |
| Power Factor Correction | 76–8 |
| Pumps | 142–4 |
| Pyrex | 137 |
| Radio Interference | 90 |
| Ramsay | 2, 5 |
| Rayleigh | 2 |
| Regulations | 23 |
| Reimer | 138 |
| Rhumkorff | 111 |
| Ribbon Burner | 134 |
| Ripple Tubes | 147–8 |
| Rotary Converter | 70–2, 156 |
| Rubidium | 163 |
| Selling Neon | 92–8 |
| Series Wiring | 44 |
| Shell Type Transformers | 153–4 |
| Sine Curve | 152 |
| Single Outline Letters | 14 |
| Sinusoidal | 78 |
| Sky Signs | 27 |
| Soda Glass | 137 |
| Sprengel's Pump | 111 |
| Sputtering | 82, 129, 159, 160 |
| Striation | 120 |
| Striking Potential | 118–121 |
| Striking Voltage | 116, 156 |
| Strip Lighting | 61–3 |
| Switch Gear (L.T.) | 68–9 |
| Taking Particulars | 98–100 |
| Teak | 32 |
| Templates | 131 |
| Thermal Strain | 137–8 |
| Time Switches | 79 |
| Transformer Positions | 38 |
| Transformers | 151–7 |
| Travers (Dr.) | 3, 5 |
| Trough Letters | 66 |
| Uralite | 12 |
| Uranium | 147 |
| Varley | 111 |
| Vee Signs | 11 |
| Volt | 29 |
| Watt | 29 |
| Xenon | 4, 113 |

# CROSBY LOCKWOOD TITLES

## Aircraft Progress and Development

By Captain P. H. SUMNER, late R.A.F., author of "Science of Flight," etc. With a wealth of illustrations this book demonstrates the various types of aircraft and their construction—the Power Unit, Commercial and Military Aeroplanes, World's Air Records and Distance Flights. A world picture of technical research and progress in a form attractive not only to Naval, Military and Air Force Personnel, but to all concerned with aeronautics. 288 pages. Demy 8vo. 236 illustrations. 25s. net.

## Piles and Pile Driving

A comprehensive and authoritative work on modern Methods and Materials. By A. C. DEAN, M.C., M.Sc., M.Inst.C.E., M.Inst.M.E. 250 pages. Small Royal 8vo. 142 illustrations. About 42s. net.

## The Theory of Vibrations for Engineers

By E. B. COLE, M.Sc. (Bristol), A.M.I.A.E., Lecturer in Mechanical Engineering at the University of Liverpool. An Intermediate Course. For Engineering Students, Designers and all making a first serious study of the subject. 250 pages. Demy 8vo. 55 diagrams. About 15s. net.

## Symbols for Designers

A Handbook on the application of Symbols and Symbolism to Design in Stone, Granite, Marble, Wood, Metal, etc. For the use of Architects, Sculptors, Ecclesiastical and Memorial Designers, and Commercial Artists. By ARNOLD WHITTICK. 160 pages. Royal 8vo. Fully illustrated. About 12s. 6d. net.

**Crosby Lockwood & Son, Ltd.**
**Stationers' Hall Court, London, E.C.4**

Digitized by:

ASSOCIATION
FOR
PRESERVATION
TECHNOLOGY,
INTERNATIONAL
www.apti.org
Australasia Chapter

**BUILDING
TECHNOLOGY
HERITAGE
LIBRARY**

https://archive.org/details/buildingtechnologyheritagelibrary

from the collection of:

Miles Lewis, Melbourne

funding provided by:

the Vera Moore Foundation, Australia